ENVIRONMENTAL PROCESSES, SOCIAL PERSPECTIVES AND ECONOMIC VALUATIONS OF THE COAST

A Dissertation

by

AMY M. WILLIAMS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2010

Major Subject: Forestry

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Approved by:

Chair of Committee,	Russell A. Feagin
Committee Members,	Ben Wu
	Sorin Popescu
	Scott Shafer
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ABSTRACT

Environmental Processes, Social Perspectives and Economic Valuations of the Coast. (August 2010)

Amy M. Williams, B.S., Rutgers, the State University of New Jersey,

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Chair of Advisory Committee: Dr. Russell A. Feagin

Coastal ecosystems provide important resources for social, economic and environmental capital to global and local communities. Socially, coastal ecosystems provide a place for people to recreate and get in touch with nature. Economically, tourism, fisheries, and businesses are dependent upon coastal resources. Environmentally, coasts provide habitat for diverse species of flora and fauna, and protection for watersheds and anthropogenic structures.

This research investigates three studies in order to provide information on social, economic and environmental issues in Matagorda, Texas. The first study uses LIDAR (Light Image Detection-and-Ranging) scanning, a remote sensing methodology that uses laser pulses to collect X, Y, and Z coordinates, to evaluate coastal changes after Hurricane Ike. Results suggest that landscape loss occurs immediately after the hurricane, but recovers and fluctuates throughout the year. Also, different areas of the dunes show unique changes during different times of the year.
The second study uses questionnaire surveys to collect demographic, social perspectives and opinions and economic information about coastal users on Matagorda Peninsula. The questionnaire investigates the most important characteristics to beach users, opinions and perceptions about beach safety, activities, maintenance and presence of seaweed, information about their trip, cost of their trip and demographics. The results provide broader knowledge about the beach users in Matagorda and indicate that while direct costs of using the beach are minimal, the indirect and intrinsic costs are much higher which result in a greater overall use value.

The third study investigates the use of the sargassum, a natural marine subsidy, as a fertilizer for dune plants. Beach raking provides a cleaner, more aesthetically pleasing experience for beach users but alters the natural design of the ecosystem by subsequently moving sand, nutrients, subsidies for habitat and fauna from the fore-beach to the dunes. Results show that sargassum

does have potential as a natural fertilizer as it did not negatively affect any of the species. The results could be used to alter management practices in order to capitalize on this natural resource while still providing a clean sandy beach for recreationalists.

These three studies together provide ecological information about coastal functions and processes that can help in creating broad holistic science based management strategies.

DEDICATION

I dedicate this paper to my parents who took a summer trip every year to Ocean City, New Jersey and inspired my love of nature and always encouraged me to follow my dreams. I also dedicate this paper to David Nannen, who has provided me with so much love and support during this process and I cannot express my appreciation for him enough.

I also dedicate this manuscript to the future surfers, beach combers and scuba divers who are aware of how fragile our coastal resources are and encourage them to always make a difference in small ways everyday.

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I can't thank David Nannen enough for his revisions and support throughout this process and for administering surveys for the pilot study.

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… Dr. Ben Wu for being a mentor, providing examples of being a great teacher and managing large and small classes, providing sound answers to questions when in a state of confusion and always having a smile that would brighten my day;

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10 and 06-019). The views expressed herein are those of the author and do not necessarily reflect the views of NOAA or any of its sub-agencies.

NOMENCLATURE

3D	Three Dimensional
AOI	Area of Interest
ICWW	Intracoastal Water Way
LCRA	Lower Colorado River Authority
LIDAR	Light Image Detection and Ranging
NOAA	National Oceanographic and Atmospheric Administration
QTM	Quick Terrain Modeler

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1. INTRODUCTION

Coastal ecosystems are an example of a complex, dynamic environment with many interacting parts. Coastal zones are the mixing locations of terrestrial and aquatic systems. Coastal ecosystems provide invaluable resources for social, economic and environmental capital to global and local communities (Costanza and Farley 2007). The coastal ecosystem provides a place for people to meet, socialize, spend family vacations and get in touch with nature. Also, recreational activities are typically related to the natural resources provided by an area (Bergstrom et al. 1990). Management for tourism and subsequent development should focus on sustainable practices that will enhance social, economic and environmental capital. An ecosystem approach is needed in order to study coastal systems to develop holistic management strategies that take multiple aspects and impacts into consideration.

Environmentally, the coast provides habitat for diverse species of flora and fauna and protection for watersheds and anthropogenic structures. Coastal resources play a vital role in providing ecosystem services that are considered natural capital, such as fisheries habitats, flood protection and biodiversity (Daily et al. 2009). Often the natural environmental characteristics (ie storm protection to houses by dune systems or provision of a sandy beach) are sacrificed for anthropocentric needs of the coastal community (McGlashan and Williams 2003, Perez-Maqueo et al. 2007). Protecting integral ecosystem processes and functions is important to sustain the environmental resources that support the overall community.

Tourism has an immense economic impact on coasts (Alan et al. 1997) and is dependent upon the coastal ecosystem to thrive. The aesthetics of clean, sandy beaches is thought to be the major attraction for tourists in order to allow for sunbathing and recreating (Sarda et al. 2009). Other activities that draw tourists are fishing, surfing, boating, shopping and culture. Many of the infrastructures and supplies for these activities (ie roads, houses, hotels and chartered fishing boats) threaten the natural capital of the environment (ie fisheries and wetland structures) that

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This dissertation follows the style of Environmental Management.

initially attract people to the coast (Bush et al. 2004, Phillips and Jones 2006). Economic capital can be increased through social capital if social capital such as coordination and cooperation exists at both micro and macro levels of society (Woolcock 1998). In coastal communities, economic capital can not be sustained long term if it detrimentally affects the natural and social capital.

Both natural and human forces can threaten the integrity of coastal ecosystems. Human forces include direct destruction through infrastructure development, unsustainable nourishment projects, destructive management practices hard structures located in critical areas and pollution (Bush et al. 2004, Phillips and Jones 2006). Natural forces include erosion from long-shore drift, wind, rain runoff, sea level rise, hurricanes and other minor storm events (Gaddis et al. 2007). Spatial and temporal aspects of coastal processes need to be taken into consideration when developing coastal management strategies (Cooper and McKenna 2008, Koch et al. 2003). There are many feedback loops between the different forces of the coast that need to be analyzed and understood holistically in order to make better management decisions (Williams et al. 2009).

Coastal management has been the focus of many researchers and other stakeholder groups. The Coastal Barrier Island Network (CBIN), an international research group, has focused their initial two meetings on developing a research-management-outreach framework for sustaining coastal barrier ecosystems under global change such as increased storm activity and continued anthropogenic stresses. During their first two meetings, members worked together to develop the following six key statements for identifying critical areas for future research and science-based management decisions to sustain coastal barrier ecosystems (Williams et al. 2009):

- *There are critical differences between natural and human-dominated barrier island landforms and ecosystems due to biophysical processes, spatial and temporal dynamics, and anthropogenic modification.*
- *The processes that influence vulnerability and resilience of coastal barrier ecosystems must be better understood across a broad spectrum of spatial and temporal scales (micro- to macro-scale).*
- *Economic valuation tools such as cost-benefit analysis and rapid assessment methods utilizing remote sensing, GIS, and field-validation techniques can be used to generate collaborative solutions for advocates of different stakeholder perspective.*

- *We need new mechanisms for communicating more effectively with stakeholders (decision makers, government agencies, teachers, local public, developers, etc.) about emerging science and the implementation of management strategies.*
- *We need to address the idea of managing for stabilization versus sustaining natural processes, along with a more integrated application of restoration alternatives that would include native flora and fauna.*
- *In the future, there is potential for the development of a unified conceptual framework for managing soft-sediment coasts, although there is much work to be done towards reaching this goal.*

These six key statements identify current research gaps in managing coastal ecosystems. Projects that focus on the six key points will provide our coasts with a stronger, more integrated and sustainable management regime that will benefit all three types of capital: economic, social and environmental.

While there are many obstacles to producing holistic studies of ecosystems, attempts to recognize the broader scales of ecosystems is necessary (Savory and Butterfield 1999) and can be aided by understanding patterns and processes that occur at a smaller scale. Ecosystem approaches are also necessary for sustainable management for both current and future generations (Slocombe 1993). Therefore, while studying coastal systems, I feel it is pertinent to use an ecosystem approach that looks beyond the sandy beaches to other interacting aspects of the coast in order to understand how to best manage a dynamic system. Therefore, I will be studying three aspects of the coast that might on the outset look to be separate, but in reality are interacting parts of a larger system in both spatial and temporal considerations. While one researcher cannot possibly perform all the necessary research for holistic management of the coast, I admit that these studies are just the beginnings of a holistic research project that would need to be combined, expanded, monitored and adapted for a greater understanding of coastal processes.

While this research is applicable to other areas, the main study site is Matagorda Peninsula, Texas, located approximately 160 km south of Houston and 160 km west of Galveston Island. On the peninsula there is a 22 mile beach that is frequented by many recreationalists.

The beach and East Bay of the peninsula are bordered by the Colorado River to the west and the Intracoastal Water Way (ICWW) to the north. The beach is part of the 1,600 acre Matagorda

Bay Nature Park managed Lower Colorado River Authority (LCRA). LCRA also is in charge of the Matagorda Nature Center, RV park and the Pavilion facilities (picnic benches, bathroom facilities, and open air showers) that are adjacent to the entrance to the beach and public parking area. Additionally, a fishing pier projects out into the water, however due to Hurricane Ike, it is partially closed off. The entrance to the ocean from the river is highly used by local fisherman and recreationalists. However Hurricane Ike and other natural processes created sand bars that have resulted in the need for construction to re-open the entrance.

Recreational activities in Matagorda include kayaking, fishing, beach walking, surfing, boating, RV camping, beach recreating, beach camping, and beach driving. The local community has a few local seafood restaurants, a local convenience store and gas station, low-key motels that are aimed towards fishermen and RV campers and bait shops. There are many modest vacation homes along the river and the beach. In 2009, an old swing-bridge was replaced by a high-rise bridge over the ICWW for access to the barrier island. This bridge has caused some local citizens to worry that the new access to the barrier island will be appealing to large corporate hotels that will come in to their local town and create large resorts that will change the community dynamics.

This research takes into consideration the suggestions by CBIN by designing three studies that will provide better understanding of three aspects of coastal processes. The first study analyzes the impacts of a major hurricane on coastal formation of dunes and the natural recovery after the hurricane. This study looks at sediment and vegetation volumes and how they fluctuate throughout different times of the year. The use of modern technology, LIDAR (Light Image Detection and Ranging), helps to aid with analyzing the processes that were occurring. LIDAR is a remote sensing technology that uses laser pulses to collect ground data based on multiple returns to produce X, Y, and Z coordinates to create a highly accurate 3D profile of the beach. LIDAR has been used in recent research studies to analyze volumetric changes coastal areas (Blott and Pye 2004, Gares et al. 2006, Robertson V et al. 2005, Sallenger et al. 2004, Shrestha et al. 2005, Zhang et al. 2005). Some advantages of LIDAR over traditional methods are the provision of a more extensive 3D profile and a quicker time return of the data (Ali and Mehrabian 2009, Brock et al. 2002, Hart and Knight 2009, Revell et al. 2002, Stockdon et al. 2002). The results of this study should help in determining what aspects of hurricane destruction are most detrimental to coastal processes and how management strategies can be designed in order to compensate for both the immediate impacts of hurricanes and other natural processes that occur throughout a year.

The second study looks at cultural and social aspects of beach users in Matagorda in order to determine how the current users are connected to their environment and what economic capital is provided by the use of the coast. The questionnaire surveys provide demographic, social perspectives and opinions and economic information about coastal users from different seasons on Matagorda Peninsula. Questionnaires are a common method for acquiring user information from coastal areas (Morgan 1999, Morgan et al. 1993, Roca 2009, Roca et al. 2008). This questionnaire asks respondents to rank aspects of the beach from most important to least important and rank which aspects need the most improvement to need least important. Then, Likert scale statements are used to determine public perceptions about beach safety, activities, maintenance and seaweed. Lastly, demographic and economic questions about their trip are used to determine direct, indirect and intrinsic values to the beach users.

Beach raking is a common management practice that uses mechanical equipment to provide a cleaner, more aesthetically pleasing experience for beach users by moving wrack off of the fore-beach and depositing it at the base of the dunes. However, this alters the natural environment by subsequently moving sand, nutrients, subsidies for habitat and fauna from one coastal niche to another. The third study looks at how this culturally considered nuisance, seaweed, can be used in a method that not only provides to aesthetically clean beaches but also helps to increase natural capital of dune plants. Sargassum is a natural subsidy to the beach and may be beneficial to dune plants as a fertilizer in the nutrient poor coastal sediment (Anthony et al. 2006, Bouchard and Bjorndal 2000, Heatwole 1971, Hemminga and Nieuwenhuize 1990, Ince et al. 2007, Lewis et al. 2007, Orr et al. 2005, Polis and Hurd 1995, Tsoar 2005, Williams 2007). If sargassum is determined to be beneficial to dune plants, then management practices could be altered in order to capitalize on this natural resource.

The three studies encompass an ecosystem approach that can be used to begin to holistically manage the ecosystem. For example, by understanding how the system recovers after a hurricane, management strategies can determine where funding could most efficiently be spent based on what aspects will recover naturally and which need more help. Additionally, it will be helpful to understand what beach users feel is lacking or needs improvement in order to place effort in fixing these items instead of improving others. Determining how much economic capital is created based on the natural and social resources of the community will also help to determine how many funds should be used for beach management in cost benefit analyses. Lastly, understanding how seaweed interacts with dune plants can help managers to more fully understand the processes that will occur when anthropogenic cleaning of the beach must be performed. These different aspects of the beach can be put together to begin to see a broader picture of the coastal ecosystem.

Specifically, the objectives of this research are:

(1) In order to understand the patterns and process of recovery after Hurricane Ike, coastal changes on a dune system on Matagorda Peninsula were analyzed over one year based on terrestrial and aerial LIDAR data by hypothesizing that:

   a) the most volume loss from the system occurs immediately after the hurricane,

   b) based on volume changes, over a year time period, sediment is returned to the system,

   c) embryonic and established dune systems would experience different volume changes and

   d) results for landscape volume changes are similar in both terrestrial and aerial LIDAR analysis;

(2) In order to determine the most important aspects of Matagorda Peninsula and develop better management strategies for the ecosystem, a questionnaire survey of beach users was analyzed by:

   a) determining demographic characteristics,

   b) determining perceptions and opinions,

   c) ranking the most important characteristics of the beach,

   d) ranking what aspects of the beach need the most improvement and

e) determining the costs users spend on a typical beach day through economic analysis of direct, indirect and intrinsic values;

(3) In order to better understanding how to manage a societal nuisance in a sustainable manner, analysis of how dune plants respond to sargassum was done by hypothesizing that:

a) plants with treatments of sargassum will grow significantly more than plants without sargassum (the controls) and

b) plants with multiple frequency additions of sargassum will grow significantly more than plants with single frequency addition of sargassum.

2. USING LIDAR TECHNOLOGY TO ANALYZE THE SEDIMENT LOSS IMPACTS OF HURRICANE IKE ON MATAGORDA PENINSULA, TX

2.1 Introduction

Episodic events, such as hurricanes, cause catastrophic damage to both natural and anthropogenic structures along the coast (Bush et al. 2004, Gaddis et al. 2007, Phillips and Jones 2006). Hurricane Ike, the fifth largest hurricane in the Atlantic Ocean during 2008, reached Category 4 classification on September 4 before hitting Haiti, Buca and Turks and Caicos Islands (Davenport 2008). Ike then proceeded to make direct landfall on Galveston Island on September 13 as Category 2 (Berg 2009, Kraus and Lin 2009). Ike caused over 60 fatalities, with about half occurring in Texas, along with up to $12 billion of damages to onshore property (Schwartz 2008) and offshore oil rigs (Rach 2008). Environmentally, Ike caused drastic sediment erosion and over-wash destruction throughout the Texas coast (Williams et al. 2009). At the study area on Matagorda Peninsula, winds from Hurricane Ike reached a maximum of 95 knots and storm surge reached approximately 3.3 m (Berg 2009). The hurricane surge inundated the beach and left a visible scarp line that cut into the primary dune ridge.

Traditional techniques to evaluate coastal changes have often lacked the ability to capture the range of spatial heterogeneity in three dimensions. Remote sensing technology, such as aerial photography and satellite images, have recently been implemented to produce quick and reliable evaluation of coastal processes (Brock and Purkis 2009, Delgado-Fernandez et al. 2009, Klemas 2009) that are pertinent to recovery after an event such as Hurricane Ike. Though these methods have decreased the time return on coastal analysis, there are still issues with collecting data, such as the ability to penetrate cloud cover and capture data at night (Li and Liu 2009, McCulloh and Heinrich 2009, Ramsey et al. 2009). The development of LIDAR (Light Image Detection-and-Ranging) scanners that use laser pulses to collect ground data based on multiple returns to produce X, Y, and Z coordinates (Bater and Coops 2009) has provided coastal scientists with a more extensive and time effective technique for studying coastal changes (Ali and Mehrabian 2009, Brock et al. 2002, Hart and Knight 2009, Revell et al. 2002, Stockdon et al. 2002).

Commonly, LIDAR data is collected by flying equipment on a plane, referred to as airborne or aerial LIDAR. This method is helpful in quickly providing time sensitive data from hurricane impacts (McCulloh and Heinrich 2009, Sallenger 2007) in areas where in-situ data is difficult to collect due to the conditions on the ground. The disadvantages of this method are the cost to fly the equipment, the availability, the approximate 1 cm resolution and 10 cm vertical accuracy. Alternatively, a LIDAR scanner can be mounted on a tripod to collect data in smaller areas, and is commonly referred to as ground-based or terrestrial LIDAR (Tao et al. 2008). For example, one study used a LIDAR station mounted on a truck to study rows of trees (Rosell Polo et al. 2009). Terrestrial LIDAR is capable of data collection in a 360 degree horizontal rotation and a 270 degree vertical rotation. Terrestrial LIDAR data can be collected from multiple areas of a site and merged together through computer software to create a 3D virtual image. Advantages of terrestrial LIDAR are that it can obtain data to less than 3 mm accuracy on precise study areas, higher availability to choose your location and less cost after the initial equipment is obtained.

A major advantage of LIDAR over traditional rod and survey transects is the provision of a 3D profile of the study area, instead of sub-samples from transects. Since coasts can be dynamic even within small areas, this provides for a more accurate measurement of sediment characteristics and changes (Zhang et al. 2005). With LIDAR, data can be collected over relatively large areas in short time periods, allowing for detection of coastal changes (Blott and Pye 2004, Brock et al. 2002, Gares et al. 2006, Robertson V et al. 2005, Sallenger et al. 2004, Shrestha et al. 2005, Zhang et al. 2005) that provide advanced information to compare different management practices (White and Wang 2003, Young and Ashford 2006).

In this study, we analyze the impacts of a major hurricane on coastal formation of dunes and the natural recovery after the hurricane. This study looks at sediment and vegetation volumes and how they fluctuate throughout different times of the year. The use of modern technology, LIDAR, helps to aid with analyzing the processes that were occurring. The results of this study should help in determining what aspects of hurricane destruction are most detrimental to coastal processes and need human management to deal with the impacts. Specifically we examined the change in sediment and vegetation volumes on a section of dunes on Matagorda Peninsula over a year time period using a terrestrial laser scanner during five sampling dates: September 2008 prior to Hurricane Ike landfall, September 2008 after landfall, December 2008 (winter sample), May 2009 (spring sample) and October 2009 (a year after landfall). We also analyzed aerial LIDAR data from April/May 2006 and December 2008 to estimate change in volume caused by the hurricane on the scanned plot. We hypothesized that: (1) the majority of volume loss would occur immediately after the hurricane, (2) most of the volume loss would be returned to the site after a year, (3) embryonic and established dune systems would experience different volume changes and (4) calibrated terrestrial and airborne LIDAR would yield similar volume estimates.

These hypotheses are important to understanding the patterns and processes that occur after a hurricane in order to implement management strategies that will focus on the most needed recovery actions. In regards to the first and second hypothesis, landscape loss is often dramatic immediately after a storm, but coastal systems have natural methods of recovering. If after a year much of the sediment is returned to the system, then re-nourishment projects may be unnecessary. The third hypothesis that looks at whether different locations have different impacts can help to discover how different aspects react. Understanding the change in vegetation in different areas of the beach at different times of the year could help managers to understand where and when to re-plant dune systems or whether it is even necessary. The last hypothesis is important in testing which of the modern methodologies for studying the coast are most appropriate for studying landscape, sediment and vegetation changes. Which method is most appropriate can help to determine cost benefit analysis of time and money spent on collecting data.

2.2 Methods

2.2.1 Terrestrial LIDAR

2.2.1.1 Data Collection

The first survey of the 100 m X 100 m plot, which stretched from the dunes to the waterline, was performed on September 10, 2008 (PRE) using a terrestrial LIDAR Scan Station 2 (Leica Geosystems AG, Heerbrugg, St. Gallen, Switzerland, Scan Station 2). Reference targets were set up throughout the site to aid in merging multiple scans from the same data set to create a more intense 3D image.

We then surveyed the same 100 m X 100 m location on September 26, 2008 (POST1), Dec 11, 2008 (POST2), May 19, 2009 (POST3) and Oct 24, 2009 (POST4) (Table 1) using the same equipment as the PRE Hurricane survey. The point density in points per m2 of the data were 9767.37 for PRE, 1139.00 for POST1, 456.64 for POST2, 1275.92 for POST3 and 13081.72 for POST4. The densities differ from date to date due to changes in surveyor methodology.

Due to lack of permanent structures on undeveloped coastal beaches, repeat measurements were difficult to get in the exact locations. Survey stakes (rods 1.3 m long) were placed on the beach and in the dunes, but were not able to be located on subsequent visits due to the rearrangement of sand by the hurricane. Additional survey stakes were placed in the dunes during POST2 and all targets were then placed on top of these survey points. During POST3 and POST4, PVC pipes were placed on top of the survey stakes for ease of identification in the computer software. GPS points were taken of the LIDAR station and the reference targets, for all dates.

In the first data set (PRE), the LIDAR scans were taken of the study area from 3 locations: at beach front and on top of the dune at the west and east extents of the study area. After preliminary analysis of the data, the next sampling set took data from three sites at the east, west, and center of the study area, but all were located along the beach front. Further data analysis determined that only two scans, the east and west corners of the study area located along the beach front, were pertinent for the data analysis, which provided a more efficient, less time consuming method for subsequent collections.

Table 1. Sampling dates and visual observations.

NAME	Date	Focus	Visual Observation
PRE	Sept 10, 2008	Baseline measurement	Baseline
POST1	Sept 26, 2008	Changes from Hurricane Ike	Erosion, approx. 3 m scarp
POST2	Dec 11, 2008	Accretion or erosion since POST1	Little change, smoother dune contour
POST3	May 19, 2009	Spring accretion or erosion	Accretion, but not full return to baseline, reestablishment of plants
POST4	October 24, 2009	One year after Hurricane Ike	Erosion from POST3, but less than after Hurricane Ike

2.2.1.2 Data Registration

Cyclone, a 3D Point Cloud Software program (Leica Geosystems Inc., 2001-2009, version 6.0.3), was used to extract and visualize the LIDAR data. Data scans from the same date were automatically combined through co-registration of common points by Cyclone. The combined data scans were then imported into Quick Terrain Modeler (QTM, Applied Imagery, USA, 2009 version 7.0.0) by converting the ASCII XYZ files into ungridded point clouds (Figure 1a).

The five data sets were aligned by producing linear transformation equations for the x, y and z variables based on offsets extracted by matching concordant locations from features in the first four data sets with the POST4 (October 2009) data set as it provided the most accurate alignment to the true position. Features included a fence, a partially-buried large drift log, a sign and posts. The standard error of the transformation was acceptable for three of the data sets, however it was quite large in the PRE data set (Table 2) likely due to lack of common points in the vertical direction because of hurricane destruction. In order to manage for this large standard error, data had to be manually overlaid in the appropriate x-y locations using the Set Model Position tool in QTM, which retained the correct z values for the data set.

Next, an Area of Interest (AOI) was selected so that subsequent analyses would be consistent across all of the data sets. POST3 was used to determine the southern extent of the AOI because it had the most landward presence of tracks formed by cars driving on the beach. Both the eastern and western extents of the AOI were limited by the presence of gaps and shadows larger than 1 m in data from PRE. The Northern extent was selected as the location where the LIDAR scanner was not able to distinguish ground level based on POST3. In all directions, the data was cut on a straight line at the point in which gaps in the data were minimal to decrease errors in gridding. Anthropogenic structures (a fence line and sign) were removed manually through QTM on the applicable data sets.

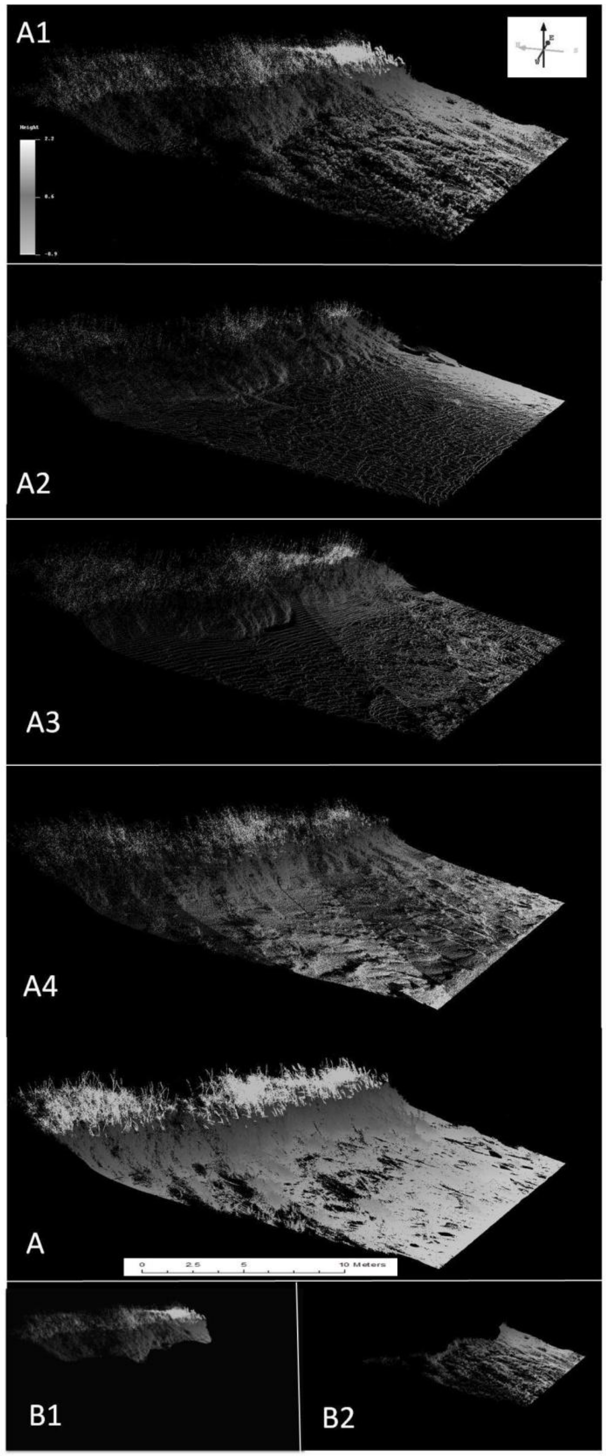

Figure 1. Landscape (raw point) data for the five data samples. (A1) Pre-Sept10, (A2) Post-Sept26, (A3) Dec, (A4) May, (A5)October. Example of raw point data for only the (B1) Established and (B2) Embryonic Dunes.

Table 2. Regression statistics used to align the data sets to the October location

Regression Statistics from POST3 Transformation			
Sample	Variable	R Square	Std Error
PRE	X	0.999	0.694
	Y	0.993	0.964
	Z	0.969	0.229
POST1	X	1.000	0.176
	Y	1.000	0.214
	Z	0.984	0.109
POST2	X	1.000	0.114
	Y	1.000	0.107
	Z	0.968	0.120
POST4	X	1.000	0.025
	Y	1.000	0.038
	Z	0.997	0.064

2.2.1.3 Landscape, Sediment and Vegetation Change Analysis

Three variables were analyzed for each of the data sets: landscape (the combination of sediment and vegetation volume), sediment and vegetation volume. The analyses were performed by creating gridded models for landscape values using the Convert Data Type tool in QTM at resolutions of 0.05 meters, 0.10 meters, 0.50 meters, 1.00 meters and 5 meters. It was found through visual inspection that the 0.05 and 0.1 meter grids were too fine for subsequent analyses as there were gaps in the raw point data and plateau-like features in the gridded results most likely caused by the shadow gaps that were larger than the chosen resolution. Therefore, only the results for 0.5, 1 and 5 m resolutions will be presented. Due to the default grid size for conversion being 1 m in QTM, coordinates had to be multiplied by 10 to convert to decimeters in Microsoft Access in order to create gridded models of size 5 to produce results in 0.5 m. Conversion to 5 m grids produced some undesirable traits in the data due to the need for neighborhood statistics. However, this resolution was left in the analysis to compare the targeted gridding size (1 meter) to a size of sampling that is commonly used by standard ground sampling field methods, such as might be done at discrete points spaced at 5 m with a Total Station or transit and rod survey (Williams et al. 2008). The landscape volume changes were computed using the Volume Calculation tool in QTM by subtracting prior sampling date gridded data from each gridded date (ie POST2 landscape change = (POST2 gridded data)-(POST1 gridded data)).

Next, the Above Ground Level (AGL) tool in QTM was used to extract the ground level from the overall landscape data. This method filtered the data set, leaving only the lowest z return points. Sedimentary volume changes were then computed using the Volume Calculation tool by subtracting prior sampling date ground level data from each sampling date (ie POST2 sediment change = (POST2 ground data) – (POST1ground data)). Vegetation volumes were calculated for each sampling date by subtracting the ground level data from the landscape data for each date (ie POST2 vegetation volume = (POST2 gridded data)-(POST2 ground data). To produce volume change, the vegetation amounts were then determined by subtracting prior sampling date vegetation volume from each sampling date, mimicking the process done for the other two variables. However, this difference in calculating the results produced some discrepancies which will be explained in the discussion.

We also partitioned the data sets into two categories to assess changes in different ecological locations: embryonic dunes versus established dunes (Figure 1b). First, we manually separated the AOI into two sections where the embryonic dunes were considered to be the portion of the study area that was seaward of the dune slope. Then, we analyzed each section as described above for landscape, sediment and vegetation changes. Analysis was performed at the 1 meter resolution only, since that resolution was deemed the most accurate.

2.2.2 Aerial LIDAR Comparison

Aerial LIDAR of Matagorda Peninsula from 2006 was obtained from the National Oceanographic and Atmospheric Administration (NOAA) Digital Coast website for Pre-Hurricane Ike data. The data, published by NOAA's Ocean Service and Coastal Services Center, was collected by the Sanborn Mapping Company, Inc. for the Texas Water Development Board (TWDB) and Federal Emergency Management Act (FEMA) during six missions between April 9 and May 13, 2006. The LIDAR system (LH Systems, ALS50) was used to collect data at standard flight line densities of 1.4 m ground sample distances over approximately 2950 square km of Matagorda County. The data was originally in LAS format with LIDAR elevation and intensity measurements in UTM NAVD 88 Geoid 03 vertical datum and was converted to geographic coordinates and GRS80 (ellipsoid) heights by NOAA's Coastal Services Center.

Classification and quality control of the LIDAR data was performed by TerraScan software (Terrasolid Ltd, Helsinki, Finland).

Post-Hurricane Ike aerial LIDAR from December 2008 was collected by the Bureau of Economic Geology and the University of Texas at Austin, and was made available through the Coastal Resources Program of the Texas General Land Office website. The data provided a first return 1m x 1m Digital Elevation Model (DEM) of the Upper Texas Gulf of Mexico shoreline, in a strip that was approximately 300 m wide. The data was presented in ASCII raster format which was projected in UTM Zone 15. Data was collected at one sample per second using a LIDAR system (Optech Inc., ALTM 1225, serial number 99d118) flown on a Cessna Stationaire 206 aircraft in coordination with geodetic quality GPS airborne and ground based receivers. The LIDAR system was set at a laser pulse rate of 25 kHz, scanner rate of 26 Hz, scan angle of +/- 20 degrees, narrow beach divergence, altitude between 750 to 920 m above ground level and ground speed between 80 and 120 knots. Horizontal accuracy was between 0.01 to 0.03 m from ground surveys and vertical accuracy over the calibration target, after processing based on average elevation bias for each day, resulted in average root mean square errors of 0.035 m.

Landscape volume changes for the aerial LIDAR data was performed by the same methodology as the terrestrial data. Due to terrestrial LIDAR results, only 1 m grid sizes were used to analyze the aerial LIDAR. The same area of interest was chosen by referencing ground-based and aerial images. The Volume Change tool was then used to find out how much landscape volume was lost after Hurricane Ike. Due to the characteristics of the aerial LIDAR data, analysis was limited to landscape volume. This is because since only first returns were recorded, vegetation could not be distinguished from ground level.

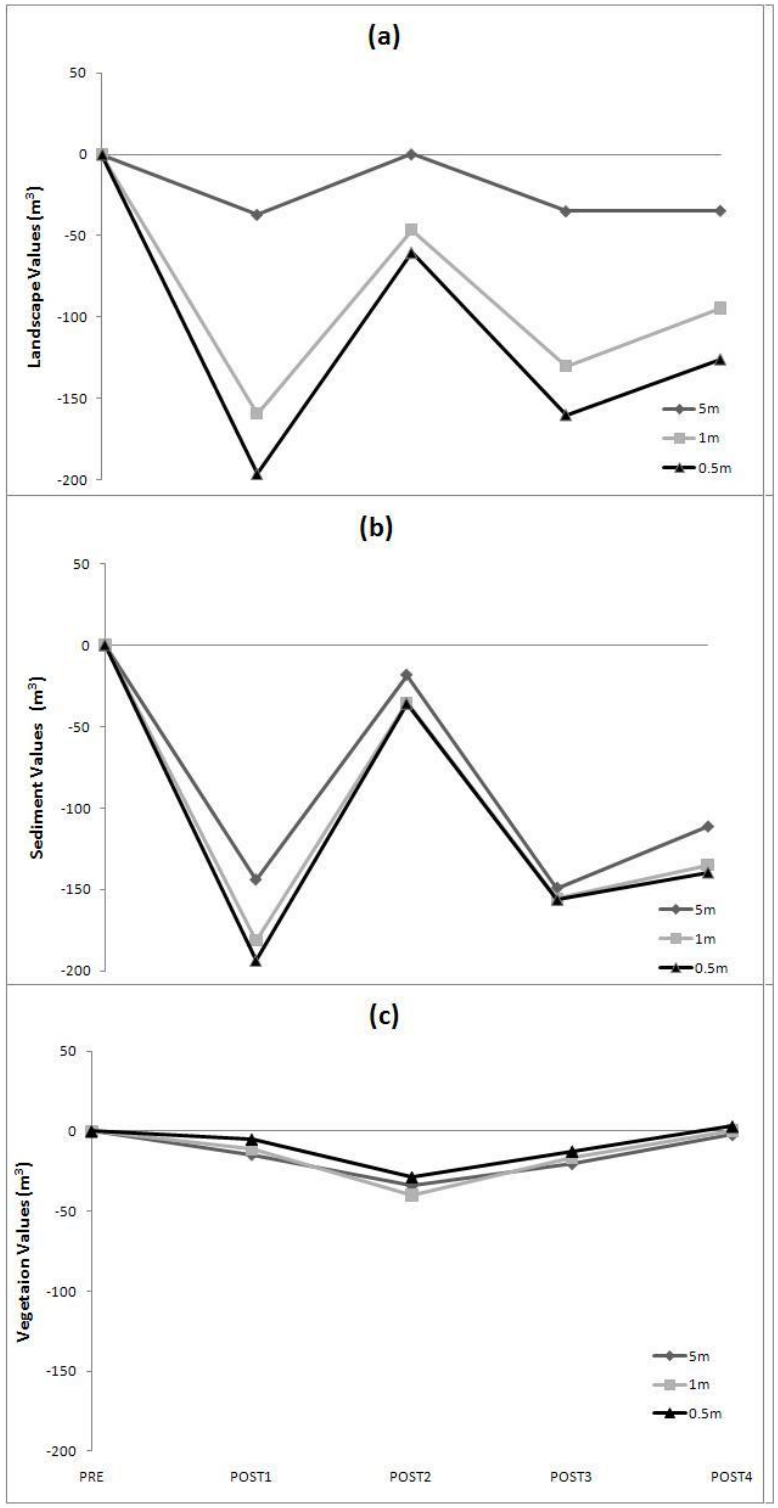

Figure 2. Differences in volumetric changes from previous dates for three resolutions for (a) landscape, (b) sediment, and (c) vegetation data sets.

2.3 Results

Analysis of the change in landscape, sediment and vegetation volumes for the whole landscape was done to test the first two hypotheses. At 1 m horizontal resolution, Hurricane Ike caused 159.32 m^3 of landscape loss and 181.39 m^3 of sediment loss immediately after the hurricane at the study site based on the terrestrial scans. After initial loss to the landscape and sediment variables, there was near recovery of landscape and sediment volume between POST1 and POST2, followed by more erosion in POST3 and then slight accretion throughout the summer months (Figure 2a and Figure 2b). Over a one year time period (PRE to POST4), 94.44 m^3 of landscape loss and 122.55 m^3 of sediment loss occurred. For all three resolutions, the direction of change is the same however the magnitude of change for the landscape variables is decreased at 5m resolution as compared to than the 1m and 0.5m grids.

Vegetation change analysis shows relatively little vegetation loss immediately after the hurricane with only 11.26 m^3 lost, but the loss doubled by POST2 with total vegetation loss increasing to 28.63 m^3(Figure 2c) Then, there was a continuous increase in vegetation during POST3 and POST4, in which vegetation recovered to PRE levels. There was only a slight gain in vegetation over a one year time period (PRE to POST4) of 0.31 m^3. The direction and magnitude of change corresponded between all three resolutions.

Next, the dunes were separated into the embryonic and established dune areas to test our third hypothesis. Both the landscape and sediment changes exhibited a major loss immediately after the hurricane with recovery during POST2 and subsequent loss by POST3 that held stable through POST4 (Figure 3a and Figure 3b). While the direction of change corresponded between dune areas, embryonic dunes initially lost less landscape and sediment volume than the established dunes. By POST3 both areas were at near similar landscape volumes, but the embryonic dunes had higher sediment volumes than the established dunes. Vegetation was also lost immediately after the hurricane and continued to decrease through POST2 (Figure 3c). However, the established dunes exhibited recovery to PRE vegetation levels by POST3 and continued to increase through POST4 while the embryonic dunes showed continued decrease through POST3 and only increased by POST4 but never reached PRE vegetation levels.

Lastly, we compared 1 m^2 aerial and 1 m^2 terrestrial LIDAR between Sept 2006 and December 2008. The analysis of the landscape volume change of the aerial images resulted in a loss of

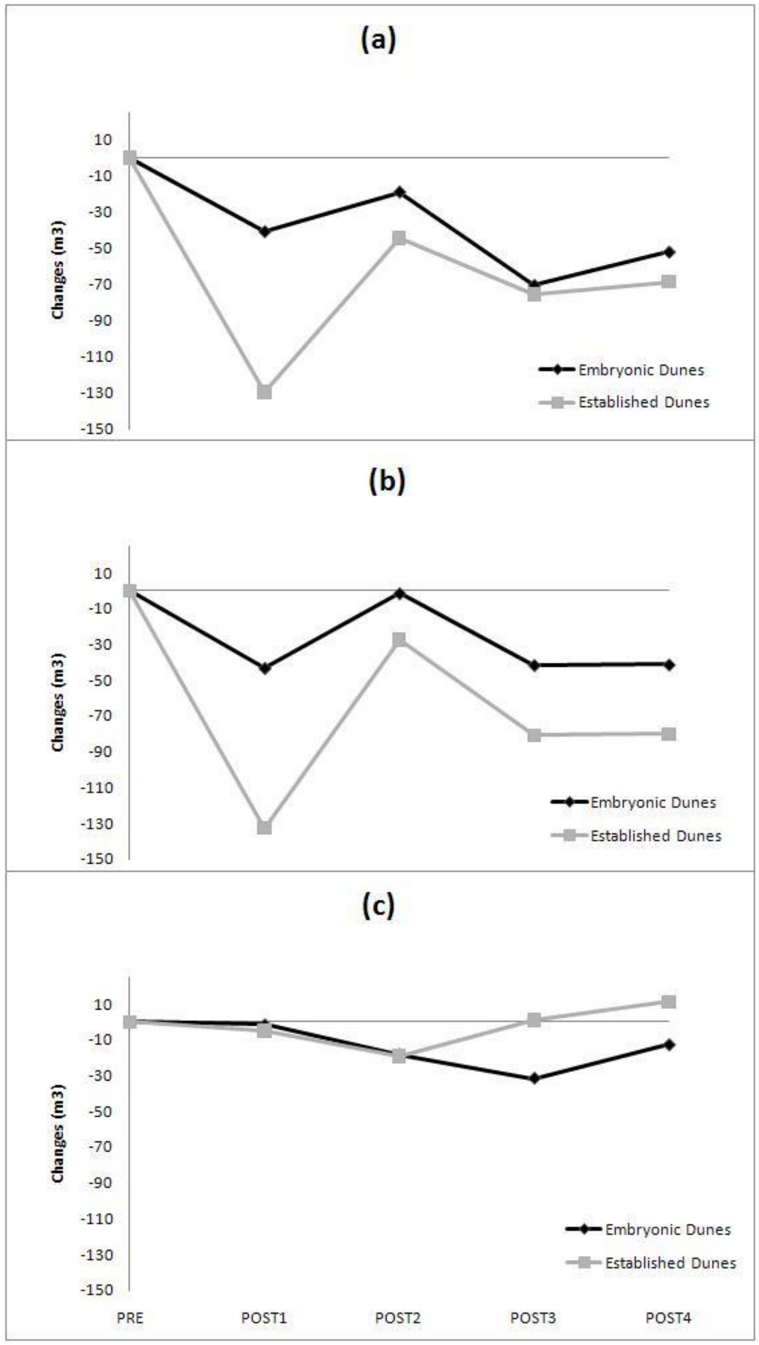

Figure 3. Differences in volumetric changes from previous dates for embryonic and established dunes at 1 m resolution for (a) landscape data sets, (b) sediment data sets, and (c) vegetation data sets.

109.1684 m^3 at 1 m resolution as compared to the 94.44 m^3 lost based on the terrestrial LIDAR results.

2.4 Discussion

Analysis indicates that though patterns are similar across the various resolutions, 5 m resolution studies (such as this LIDAR study, Total Station or rod and survey point measurements) cannot match the amount of detail that a terrestrial LIDAR system can provide. However, analysis at the finest grid sizes (0.01 and 0.05 m) caused issues in gridding of the data due to gaps caused by shadows and resolution size of the current methodology and technology. Though these issues could be managed for using data processing methods such as smoothing and interpolation (Stockdon et al. 2009), these additional steps may produce less reliability to the data and were beyond the scope of this study. Taking these issues into consideration, both 1 and 0.5 m grids were deemed best for analysis. In future studies, it would be important to determine what grid size was desired for data analysis so data collection could capture an appropriate grid size and methodology could compensate for shadow gaps.

The data supports our first hypothesis that the most landscape and sediment loss occurred immediately after Hurricane Ike, while the vegetation experienced continued loss through December (POST2). However, the conclusion about the second hypothesis that sediment returns to the system within a years' time is more complicated. The terrestrial LIDAR results indicated that by December (POST2) the system had almost recovered in both landscape and sediment volumes, but then decreased again to a slightly less loss as compared to after the hurricane. Over a one year time period, about half of the landscape and sediment volumes had re-established within the area, whereas results showed a recovered amount of vegetation through the latest sampling in October (POST4). It is interesting to note that the vegetation volume measurements are small proportionally (approximately 1/20th) to the landscape volumes; the sediment volume had the greatest effect on the overall landscape change.

These results are important for developing and implementing re-nourishment projects. While some of the sediment returned to the system, the study indicates that all of the sediment did not return. The increase of sediment volume in December was likely due to post-storm recovery as sand moved from the near-shore environment to the dunes, while erosion in spring may be due to active weather and tides. In developing management strategies, planners might want to wait until the winter to determine how much sand should be placed back on the beach. However, they would want to avoid re-nourishing the beach during the spring when erosion occurred despite a lack of hurricanes. The onset of vegetation volume increases in May were likely due to the growth of both perennial plants that go dormant during the winter season and the emergence and maximum production by annual plants at this time (Udo and Takewaka 2007). Therefore, dune restoration may need to be postponed until after spring when the annuals emerge in order to determine the areas that actually need to be re-vegetated.

Instead of a continuous recovery after Hurricane Ike, the data supports a cyclic process of erosion and accretion throughout the year in which sediment and vegetation have different cycles. Multiple years of data would be needed to determine if this is a typical annual cycle and if so, how hurricanes affect this cycle. A cyclic process would be important in understanding the ways to manage the coast and for evaluating the success of a management project.

One issue that is obvious with the results is that the vegetation and sediment change should add up to the landscape change. However, when this is done for any of the dates or the year time period, there are some discrepancies. Further investigation showed that when the ground data was gridded, the results produced results outside the boundary of the area of interest due to neighborhood calculations. When data is gridded, some errors are expected. Since vegetation amounts are calculated by the ground data being subtracted from the gridded landscape data, possibilities for errors are twice as high as compared to the calculations of the landscape and sediment data individually. While a variety of data manipulations were attempted to compensate for this issue, no appropriate solutions were discovered at this time using QTM.

The third hypothesis that different areas of the beach have different volumetric change results was only supported by the vegetation volume changes. The differences between the embryonic and established dunes provide insight into the unique responses of different areas of the beach during the same time of the year. This is important in determining where and when re-vegetation after hurricanes should occur. Both the established and embryonic dunes experienced a loss in landscape and sediment volumes after Hurricane Ike with accretion through December (POST2) and are similar to the directionality of change in the beach area as a whole.

While embryonic dunes showed a different magnitude of change, this discrepancy could be due to differences in total area of embryonic and established dunes. While the two areas took up similar 2D ground areas, the established dunes were much higher than the embryonic dunes, leading to more possible volume within the 3D profile. With more landscape volume, the established dunes most likely had more landscape volume to lose immediately after the hurricane. A baseline measurement of volume amounts would aid in comparing two locations of the dunes in future studies.

While loss of vegetation occurred in both areas after the hurricane through to December (POST2), the established dunes recovered by May (POST3) and even experienced additional vegetation in October (POST4). The embryonic dunes continued to experience loss in vegetation through May and only began gaining vegetation in October. Though the reason for this difference in growth period was not tested, some speculations can be made. The plants on the established dunes may be different species with unique growth formations (Britton and Morton 1989, Tiner 1993) that could be interpreted differently by LIDAR analysis. Sea-oats (*Uniola paniculata*), observed on top of the established dune, are tall plants that protrude into the air and would easily be picked up by LIDAR and distinguished from the ground. Morning glories *(Ipomoea sp.)* and seashore dropseed (*Sporobolus virginicus*), commonly observed on the embryonic dunes, grow low to the ground and in clumped or creeping formations that may prevent them from being distinguished from ground by LIDAR. Another reason for the difference may be that the established dunes are more protected than embryonic dunes during the summer months from natural events (ie high tides and episodic events) and anthropogenic disturbances (ie automobile and foot traffic). These results may indicate that re-vegetation projects should only focus on established dunes during the summer/high tourism season, and then focus on re-vegetating embryonic dunes during the off season.

Lastly, the test of our fourth hypothesis is inconclusive. Only the landscape volume was analyzed due to the gridded format of the aerial LIDAR that did not allow separation between vegetation and ground data points. It does appear that the loss of landscape volume was similar between the aerial and ground LIDAR, but a comparison was difficult due to differences in dates and grid resolution. The aerial data of the area prior to Hurricane Ike came from 2006, so it is hard to determine that the loss was due to Hurricane Ike, and not some other event that had taken place. It would be important to consider what the goals of a study were before managers attempted to collect data from either source of LIDAR systems.

There are limitations to our data sets and analysis techniques which could be improved on for future studies. During data collection, more permanent markers could be set in place to allow for ease of locating the area of interest during repeat scans. Also, LIDAR scans could be taken from the top of the dunes to decrease shadow gaps, providing a better resolution and a larger area of interest. Confounding factors at the coast are important to keep in mind. A different beach, where cars were not permitted, could be used in order to capture changes at the fore-beach. Additionally, multiple study areas could determine if the patterns are different along the coast. While the data over a year indicated a cyclic pattern, a longer study would be needed to determine if this is a yearly pattern, a result of Hurricane Ike or an anomaly. For data analysis, the use of an automated algorithm to delineate between the established and embryonic dunes, such as described in Stockdon et al. (2009), could be used to improve the distinction of areas of the beach. Using new methods and techniques for computational analysis of LIDAR is imperative in producing the best results for coastal evaluations (Ali and Mehrabian 2009, Hart and Knight 2009, Kempeneers et al. 2009, Leigh et al. 2009, Palaseanu-Lovejoy et al. 2009, Yates et al. 2008).

2.5. Conclusion

Overall, the study results showed that terrestrial LIDAR is able to capture more information at a finer scale than the traditional method and is able to produce 3D rather than 2D analyses. This research showed that both 1 and 0.5 m grids were best for analysis as they were able to handle gaps and the natural aspects of the beach.

The research indicated that while the most volume loss occurred immediately after Hurricane Ike, partial recovery occurred throughout a one year time period. However, the results indicated a possible cyclic pattern throughout the year. Longer temporal studies would be needed to determine the critical aspects of this possible cyclic pattern. Knowledge about coastal dynamics over a year time period can help coastal managers in determining the best strategies for re-nourishment and re-vegetation projects and the best time of the year to implement these strategies.

Different areas of the beach showed varied responses during different times of the year. Embryonic dunes did not show a recovery of volume until after May, while established dunes recovered by May. This indicates that different processes are influencing nearby areas of the dunes. Also, re-vegetation methods should take into consideration the processes that are occurring in order to provide the most efficient management strategy at the most productive time of the year.

The comparison between aerial and terrestrial LIDAR results indicates that it is important to understand analyses that will be done before collecting data. Resolution is important in analyzing data at similar densities. It is also important to determine what data will be needed for analysis. While the terrestrial LIDAR provided multiple returns that could be used to extract vegetation from ground level, the aerial LIDAR provided only first returns that created a DEM of the ground surface in which vegetation could not be extracted. Therefore, determining the data that is needed determines which method of collection would be most efficient for a study.

During episodic events, such as Hurricane Ike, quick and reliable analysis of the situation is critical in making decisions that will help to save lives. LIDAR ground scans can provide a quick and accurate method of predicting coastal changes, analyzing impacts and developing recovery plans (Klemas 2009, Ramsey et al. 2009). Also, LIDAR can be used prior to natural events to determine vulnerable areas, especially in dune structures on coasts, in order to take preemptive measures for protection (Hart and Knight 2009).

3. COASTAL RESOURCES ON MATAGORDA PENINSULA, TX: ECONOMIC VALUATION AND SOCIAL PERSPECTIVES OF COASTAL STAKEHOLDERS

3.1 Introduction

Natural features of the coasts often attract tourism but fail to capitalize on the possible economic benefits (Wood and Glasson 2005) which can lead to ill-informed decisions that exacerbate environmental degradation and cause further economic loss. Stakeholder demographics, perceptions and economic valuation are important in balancing the costs and benefits of management decisions in order to protect invaluable coastal resources.

Coastal resource values can be derived in a variety of different ways (Loomis and Walsh 1997). Physical attributes, such as sediments and vegetation, have replacement values which are represented by the restoration costs. Valuation of ecosystem services can be derived from already established techniques, such as the contingent valuation method, willingness to pay and hedonic pricing (Hamilton 2007, Howard and Julie 2008). Property tax values can be representative of the value placed on the coastal location through hedonic pricing. Access fees can represent the value of a certain area, specific natural attributes or management methods (Edwards 2009, Peters and Hawkins 2009). Travel costs, such as gas and accommodation expenses, can also be used to place an intrinsic value on beaches by coastal recreation users (Marzetti Dall'Aste Brandolini 2006). The income lost from taking days off work to visit the coast can provide the opportunity lost cost (Loomis and Walsh 1997). The valuation of ecosystem services of coastal resources can help determine the best use of funds for the overall economy (Roncin et al. 2008, Ruitenbeek 1994).

Coastal management decisions are complicated by a variety of stakeholder’s opinions and preferences about the coastal ecosystem (Innes and Booher 2004, McGlashan and Williams 2003, Parkins and Mitchell 2005, Rockloff and Lockie 2004). Stakeholders include residents, tourists, business managers (hotels, novelty shops, restaurants and concessionaires), rental agents, fishermen, naturalists, environmentalists, government entities, cruise boat owners and tour guides.

Questionnaire surveys are common tools to gain knowledge about resource users. Roca et al. (2008) used beach occupancy visual assessments along with public perception questionnaires to evaluate user satisfaction on six public beaches in Spain. The study indicated that while sand availability increased user satisfaction, high densities of users did not necessarily deter beach goers. Instead, there were other variables, such as beach slope, width, sand color and texture, cleanliness, vegetation cover, facilities (toilets/showers), parking, landscape, noise, design, comfort, quality and cost that influenced tourists' satisfaction.

Two studies done in the UK (Morgan 1999, Morgan et al. 1993) also used questionnaire surveys to determine factors that were important to beach users. In the 1993 study, the method design consisted of three parts: initial interviews, a pilot study and a final survey. The study asked demographic questions and preference questions where respondents ranked different characteristics of the beach. The characteristics of the beach that were ranked included physical aspects, human usage, commercialization, facilities, access, activities and safety. In the 1999 study, 859 questionnaire responses were used to analyze the priorities and preference of beach users of 50 different beach aspects across 23 beaches in Wales. The questionnaire consisted of five parts: socio-demographic questions, preference questions where the respondent ranked 6 aspects, priority rating questions of beach aspects, ranking questions for five major beach facets to indirectly determine landscape/scenery quality values and selection of preferred beach type from a choice of five categories that represented a continuum of possible beach types. The most important factors of beach selection were landscape and scenery, followed by beach safety and then a variety of environmental factors. Both studies found that different users had different priorities and opinions about different beach types based on their primary use types (i.e. the nature users versus beach resort users).

There is currently a lack of data on both the economic valuation and social perspectives of coastal communities in Texas which can result in management decisions with detrimental economic, environmental and social effects. The objective of this study is to use survey questionnaires to determine economic values, demographic characteristics and social perspectives and opinions of beach users to provide information that will help make better management decisions that keep in mind economic, environmental and social needs (Table 3).

Table 3. Items used to create the coastal resources questionnaire.

Questionnaire Topics	
Categories	**Examples**
Demographics	Age Income Home Residences – zip-code What recreation vehicles do they own (car, kayak, boat) Second home on island?
Perceptions	Biggest Likes of Matagorda Biggest Dislikes of Matagorda Is the beach clean? Is the beach useful for your activities as described above? Why do you choose this beach? How are prices?
Opinions	Activities partaken in – fishing, sightseeing, bird-watching, swimming, kayaking, walking, running, camping Facilities: toilets, showers, eateries, parking lots, access ways, footpaths Would you like to see any changes to the management of the beach? Could the beach be better used if other activities were initiated?
Economic Valuation	Travel cost – gas, missed work Travel Duration on this Trip Travel Days – weekend or weekdays Travel frequency - in the summer, per year During Trip spending – accommodation, food, supplies (bait, bug spray, etc) Off Site Spending – boat, tent, gear (one time buys) Willingness to pay for different management strategies

3.2 Methods

3.2.1 Measures

Examples of other surveys and descriptions of how to calculation economic use valuations were used to create the Matagorda survey. A literature review of the types of surveys used in coastal areas determined that using Likert statements and ranking questions were appropriate methods to determine user opinions and perceptions. A book on cost-benefit analysis (Loomis and Walsh 1997) was used to determine the economic variables that needed to be collected in order to produce an adequate use valuation. Lastly, general demographic values were deemed important to capture a picture of the beach users at Matagorda.

Research on designing a survey led to the Matagorda survey being created with three sections (demographic data, perspectives & opinions and economic valuations) (See Appendix A for a sample of the survey). The demographic responses provided data on age, income, sex and marital status. In the second section, Likert scale statements were used to determine respondents' perceptions of coastal aspects and issues. An example of a Likert statement is: "On a scale of 1-5, how much do you agree with the following statement: "The beach at Matagorda is clean.". Responses can determine negative and positive attitudes towards coastal issues such as safety, activities, maintenance and seaweed management. Additionally, the survey determined the user's opinions about what are the most important coastal characteristics and what needs improvement at Matagorda. Lastly, the survey asked questions about the respondent's travel costs, zip-code, group size, cars used, time taken off work, cost of supplies, accommodation costs and frequency of the trips. Calculations were created based on these results and the income information to determine direct, indirect, intrinsic and total use value of the beach.

3.2.2 Samples

The initial survey was produced in both online and paper formats. A focus group was used to determine if the survey was grammatically correct and made sense through the online format. After editing the initial survey, a pilot survey was administered on Sunday, July 12, 2009 in Matagorda by two researchers. The researchers walked on the beach from the public access point near the pier to the east for three hours (which resulted in six man hours of collection). Surveys were handed out to individuals recreating on the beach and were asked to fill out the forms while researchers waited.

The initial analysis of the survey resulted in the following modifications. The initial survey had an open ended question after each section asking the respondents to make comments on anything that was missing. However, in the final version of the survey, open ended comments were removed from each section and respondents were asked to make comments at the end of the survey on all sections. This was done to decrease the length of the survey as many respondents had verbally commented about it being too long. Some of the Likert statements were redundant and resulted in removal of one of the statements for the final survey. Typos, such as the word "by" being duplicated in one of the questions, were corrected. Font size and layout were edited to make the survey more legible in the field as many people did not have reading glasses on them at the beach. Additionally, due to many respondents not speaking English, a Spanish version of the survey was created. The only substantial addition was the inclusion of "Lack of Crowds" as an option for beach characteristics. The pilot samples were analyzed separately during final analysis.

Data was then collected at three alternative time periods (In Season, Off Season and Spring Break). These three time periods were specifically selected in order to collect a representative sample of coastal users in Matagorda. "In Season", defined as times when beach permit fees were being actively collected at the entrance to the beach, were therefore collected during 2009 on August 21 (Fri), 22 (Sat), 23 (Sun), 29 (Sat) and Sept 5 (Sat). "Off Season", defined as times when beach permit fees were not being actively collected at the entrance, were collected on January 22 (Fri), 23 (Sat), 28 (Thurs), and 30 (Sat). "Spring Break", defined as the times during March when the majority of nearby colleges and universities had off of school (March 6-21: March 6-14 for Baylor University, Texas State University and Southern Methodist; March 13-21 for Texas Tech, University of Texas, Texas A&M and University), were collected March 7 (Sat), 17 (Wed) and 19 (Fri). Data was supposed to be collected on March 8 (Sun) and 20 (Sat) but was cancelled due to weather. Data collected was attempted over a variety of days during the week but was impaired based on lack of respondents during week days and availability of surveyors. Additionally, data was collected during a variety of times during daylight hours (for safety reasons, surveys were not collected after dark) to collect a representative sample of beach users.

Questionnaires were administered to beach users on the beach and at the pavilion/facility area. The In Season surveys were collected in the same manner as the pilot surveys, in which respondents were approached by foot by the researcher and asked to complete a paper survey. If they were opposed, then they were asked to complete an online survey and were given a flyer with the website. People were not approached if they were in the water or cooking/eating a meal. At the Pavilion, most people were eating or cleaning up, so flyers were placed on cars with the website. During the year, however, surveying methodology was altered to best collect surveys based on weather and attitudes of respondents. During the first Off Season sampling, many respondents did not want to fill out the survey in person due to wind and cold weather on the beach. During subsequent sampling days, respondents were given a copy of the survey and asked to send it back or go to the website. Also, typically only one researcher was available to go into the field during the Off Season. Due to being solo, cold weather and sparseness of beach users, beach users were often approached on the beach by car or at the pavilion. During Off season sampling, many people were observed to be using the beach for only a few moments, typically to touch the sand, take a short walk or get a picture.

During the Spring Break sampling, the density of respondents was high again and the surveys were administered by foot on the beach. Many people were very preoccupied and during some days the weather was windy and cold. In order to compensate for the weather and the solo researcher, respondents were provided with paper surveys in self-addressed stamped envelopes and asked to fill them out and mail them back in the near future. This increased the amount of approached potential respondents during the days that the density of beach users was very high while decreasing the time needed in the field.

One person per group was asked to answer the questionnaire due to the way the economic section of the survey was worded. Group size was indicated in the economic section. Out of the overall 113 surveys collected, 17 surveys were collected during the Pilot sample (17 on paper in person), 47 during the summer period (32 on paper in person, 5 online), 14 during the winter period (10 on paper in person, 3 on paper by mail, 1 online), and 35 during the spring break period (4 on paper in person, 31 on paper by mail, 0 online).

3.2.3 Analysis

Statistics were calculated for the demographic responses based on each sample period and the total. Average, minimum, maximum and mode values were calculated for appropriate variables. When ranges were given, the mode was used as the statistic of choose. When open answers were allowed, the average was used. For categorical data, frequency results were provided for each category.

The Likert statements were first analyzed based on their mean, mode, standard deviation and percent agreed, disagreed and neutral for each question based on total sampling. Then, the Likert statements were then compared using a Kruskal-Wallis Non-Parametric test for ranks to determine if there were differences in the results during the four sampling periods. This test is similar to an Analysis of Variance however results are ranked in order to handle the ordinal data. To be conservative, results were analyzed at a 10% significance level. The rankings of the most important characteristics of the beach and what needed the most improvement were analyzed based on their mean and standard deviation for all sampling periods.

Economic valuation was analyzed based on the use value of the beach. Here we determine the use value of each respondent for their trip to Matagorda Peninsula using the equations below based on the indicated results of the survey.

Direct Cost per trip = *Access Fees* = Entrance Fee at Booth

Indirect Costs per trip =*Transport Fee + Daily Supplies + Fixed Costs + Accommodation Costs + Other*

Transport Fee = Gas + Wear/Tear = Distance * Travel Reimbursement Rate for Texas

Daily Supplies = Food + Drinks + Suntan Lotion + Bait + others

Fixed Costs = Fishing Rods + Tent + Kayak + RV + coolers + others

Accommodation Costs = Room/Campsite * Night

Other

Intrinsic Values per trip = *Opportunity Lost* = (Days off Work) x Salary

Use Value for Trip = Direct Costs + Indirect Costs + Intrinsic Values

3.3 Results

3.3.1 Demographics

Demographic results are provided in Table 4. The minimum average age of the respondents was 18, however, that is because children under 18 were not allowed to fill out the survey. The average income was 54,000, but the mode was 30,000. In this case, the mode is probably more applicable. The majority of the visitors were married and visited for a day trip. While group sizes ranged between 1 and 25 people, the average group was approximately 5 people. Some visitors were in Matagorda for less than a day, and some lived there all year round, but the average visit was for 8.6 days and the mode was 1 day. While most visitors did not have to take off of work, those who did were mainly there during the on-season. The most common amount of trips per year was 7 or more. However, people in the off-season typically only took 1 trip per year with an average of 20 days spent in Matagorda.

Table 4. Demographic results of questionnaires for all sampling periods.

Category	Value	Total	Pilot	On Season	Off Season	Spring Break
Surveys Returned		113	17	47	14	35
Male/Female		38/66	7/8	18/23	4/9	9/26
Age	Average	42	38	41	48	43
	Min	18	18	22	19	22
	Max	82	60	64	82	73
Income	Mode	30,000	30,000	30,000	30,000	90,000
Marriage Status Frequency	Single	23	5	12	3	3
	Married	74	9	27	8	30
	Divorced	11	3	6	1	1
	Other	3	0	1	1	1
Purposes of Visit Frequency	Day Trip	60	13	20	6	21
	Long Vacation	33	0	19	3	11
	Work	4	0	4	0	0
	Other	12	3	3	4	2
Group Size	Average	5.09	5.00	5.52	2.77	5.43
	Min	1	1	1	1	2
	Max	25	16	25	5	9
Cars Used	Average	1.68	1.71	1.96	1.15	1.51
	Min	1	1	1	1	1
	Max	6	6	6	2	4
Days Spent	Average	8.30	1.73	10.85	20.00	3.29
	Min	0.0	0.0	0.0	0.0	0.0
	Max	365	14	365	120	20
Days off Work	# who Took Off	28	4	13	1	10
	# who didn't Take Off	75	11	31	11	22
	Average Days	4.33	4.50	2.21	0.5	8.00
	min	0.5	2	1	-	1
	max	50	7	5	-	50
Trips per Year	Most frequent	7 +	7+	2-4	0-1	2-4

3.3.2 Likert Scaling

Statistical results of Liker statements are provided in Table 5. When looking at the combined data, only three questions resulted in the majority of the respondents disagreeing with the statement (enjoying off-roading activities, too high access fees, and complete removal of seaweed). When comparing the results of the Kruskal-Wallis Non Parametric test for all four sample periods, six questions (enjoying bird watching, acceptable level of trash, adequate facilities, too high access fees and appropriately used access fees) showed significant differences (Table 6).

3.3.3 Ranking

The results of the ranking means and standard deviation (Table 7) showed that for all data combined, respondents found cleanliness and safety to be the most important characteristics of Matagorda Peninsula and off roading and water sports to be least important. Also, trash and road maintenance needed the most improvement while seaweed and facilities needed the least.

Again, a Kruskal-Wallis test was used to determine if there were differences between the sample periods at a 10% significance level. The Kruskal-Wallis test found four significantly different rankings (Table 8). Cleanliness was found to be most important to Off Season respondents and nature was most important to Pilot respondents. Off-roading was least important for Spring Break respondents. Also, On Season respondents ranked trash as needing the most improvement.

3.3.4 Economics: What is the Use Value of Matagorda Beaches?

The use value calculations and examples from each sampling period are shown in Table 9. Results of economic use valuation calculated for both overall and individual sampling periods based on the equation given above in the Methods section are shown in Table 10.

One issue with the computation was the access fee amount. Only one person specified paying the $6 access fee. Therefore, it will be assumed that everyone during the pilot and on-season sampling dates paid the $6 access fee charged in 2009, everyone during the off-season did not pay an access fee, and everyone during the spring break sampling period paid the $10 access fee charged in 2010.

Table 5. Likert scale results for all questions for total sample size. *(empty & n/a responses removed). % Disagree refers to the % of responses that were given a value of 1 or 2, while % Agree refers to responses that were given a value of 4 or 5 and % Neutral refers to responses that were given a value of 3.

Question	Valid N*	Ave	Mode	Std Dev	% Dis-agree	% Agree	% Neutral
Beach Safety Questions							
Swimming at this beach is safe.	108	3.66	4	1.10	15.74	56.48	27.78
Driving on this beach is safe.	108	3.55	4	1.23	17.59	54.63	27.78
Police safety on this beach needs to be improved.	107	2.74	3	1.28	42.99	26.17	30.84
Beach Activity Questions							
I like being allowed to drive on this beach.	109	4.28	5	1.26	11.01	83.49	5.50
Fishing at this beach is enjoyable.	89	4.31	5	0.90	4.49	86.52	8.99
Being allowed to camp on this beach is favorable.	95	4.02	5	1.14	9.47	68.42	22.11
I enjoy bird-watching at this beach.	94	3.83	5	1.24	12.77	61.70	25.53
I enjoy walking/running on this beach.	108	4.35	5	0.86	2.78	83.33	13.89
I enjoy water activities/sports (surfing, bodyboarding, body surfing, kite surfing, etc...)	90	4.03	5	1.13	11.11	71.11	17.78
I enjoy off-roading/ATV/mudding activities	82	2.71	1	1.48	51.22	30.49	18.29
I like to participate in family activities (picnicking, swimming, playing, etc) at this beach.	111	4.63	5	0.85	4.50	92.79	2.70
I like to participate in partying activities (dancing, drinking alcohol, listening to music) at this beach	103	3.41	5	1.50	33.01	50.49	16.50
Beach Maintenance Questions							
The road on this beach is well maintained.	106	3.25	3	1.23	27.36	42.45	30.19
The level of trash on this beach is acceptable.	112	3.33	4	1.34	26.79	50.89	22.32
The cars do not cause cleanliness problems on beach.	108	3.61	5	1.27	16.67	56.48	26.85
The natural aspects of this beach are well maintained.	109	3.69	3	1.07	11.01	53.21	35.78
Facilities (bathrooms, showers) on this beach/adjacent areas are well maintained.	97	3.42	3	1.30	22.68	50.52	26.80
Facilities on beach/adjacent areas are adequate for my needs.	102	3.58	4	1.25	20.59	57.84	21.57
The access fees are too high at this beach.	100	2.16	1	1.38	66.00	18.00	16.00
Access fees are used appropriately at this beach.	91	3.69	5	1.34	16.48	60.44	23.08

Table 5 Continued

Question	Valid N*	Ave	Mode	Std Dev	% Dis-agree	% Agree	% Neutral
Seaweed Questions							
Seaweed on this beach does not deter me from recreation.	108	3.81	5	1.28	19.44	66.67	13.89
Seaweed is important for the natural ecosystem.	108	3.94	5	1.09	9.26	67.59	23.15
Seaweed on this beach should be left on the beach.	107	3.05	5	1.49	40.19	38.32	21.50
Seaweed on this beach should be moved to dunes.	107	3.51	5	1.50	27.10	57.01	15.89
Seaweed should be removed from beach completely.	108	2.14	1	1.33	63.89	18.52	17.59

Table 6. Likert questions that showed differences between sampling time periods.

Questions	Chi Sq	Sig	Kruskal Wallis Rank Results *			
			Pilot	On Season	Off Season	Spring Break
Beach Safety Questions						
Driving on this beach is safe.	6.88	0.076	48.38	59.39	Agree (70.00)	Disagree (46.61)
Beach Activity Questions						
I enjoy bird-watching at this beach.	6.68	0.083	50.97	48.06	Agree (64.50)	Disagree (40.21)
Beach Maintenance Questions						
The level of trash on this beach is acceptable.	12.06	0.007	54.88	Agree (46.44)	Disagree (77.69)	62.93
Facilities on this beach/adjacent areas are adequate for my needs.	8.19	0.042	Agree (38.96)	50.49	Disagree(70.79)	51.12
The access fees are too high at this beach.	6.79	0.079	53.03	46.69	Agree (36.65)	Disagree (59.35)
Access fees are used appropriately at this beach.	7.27	0.064	44.88	49.46	Disagree (60.00)	Agree (37.07)

* Kruskal Wallis values are based on ranking of the ordinal results. A lower value indicates more disagreement and a higher value represents more agreement to a statement. The values represent a spectrum of how the respondents felt.

Table 7. Ranking results for all sampling periods.

Perceptions							
Most Important Characteristics*	**Total**			**Needs most Improvement****	**Total**		
	Valid N	Mean	Std Dev		Valid N	Mean	Std Dev
Clean	112	3.10	2.37	Trash	109	3.02	1.61
Safety	110	3.98	2.98	Road maintenance	111	3.27	1.77
Driving	111	5.27	3.47	Beach safety	108	3.33	1.71
Lack of crowds	112	5.34	3.19	Nature protection	110	3.57	1.67
Fishing	111	5.63	3.13	Facilities	109	3.87	1.84
Facilities	111	5.71	2.92	Seaweed	110	3.95	1.74
Nature	111	5.76	3.11				
Travel time from home	111	7.36	3.36				
Non-driving/rec area	111	7.97	2.82				
Camping	111	7.98	2.96				
Watersports	109	8.66	3.04				
Off-roading	110	9.51	2.53				

* 1 = most important; 12 = least important

** 1 = needs most improvement; 5 = needs least improvement

Table 8. Ranking for significantly different items for different sampling periods.

Perceptions	**Chi Sq**	**Sign**	**Kruskal Wallis Rank ***			
			Pilot	On Season	Off Season	Spring Break
Are These Important Characteristics?						
Clean	6.428	0.093	Least (71.18)	54.05	Most (42.73)	57.77
Nature	11.713	0.008	Most (38.41)	53.33	52.38	Least (69.37)
Off-roading	6.795	0.079	Most (46.12)	53.40	46.33	Least (66.32)
Do These Need Improvement?						
Trash	7.522	0.057	55.85	Most (46.01)	61.88	Least (64.38)

* Kruskal Wallis values are based on ranking of the ordinal results. A lower value indicates most important or most in need of improvement while a higher value represents a less important or less in need of improvement

In order to calculate transportation costs, I used MapQuest to find the distance between the zip-code and Matagorda Beach. I then used the Travel Reimbursement Rate for the State of Texas to calculate the transportation fee (found at: https://fmx.cpa.state.tx.us/fm/travel/travelrates.php). I used the 2009 rate of $0.50 a mile for the pilot, on-season and off season respondents and the 2010 rate of $0.55 a mile for the Spring Break respondents. This rate includes both the gas costs and wear and tear on the car. Therefore, it was used in place of the gas costs reported in the surveys. This eliminates errors in the respondents' gas calculations, discrepancies between whether the results were given in one way or round trip values and only takes into account the distance between origin and Matagorda. However, a problem is this calculation does not take into account type of car or efficiency.

Some results were not useful in calculating values. One issue was that some people stated they had spent zero days in Matagorda. Since these people were approached in Matagorda, it was assumed that they spent at least one day in Matagorda, so they were given a value of one. This discrepancy may have been because people might have felt that they had to be there a full 24 hours to count the trip as a full day. For most results that were left blank or n/a, the value had to be considered "missing" in the analysis. However, if cost per night was blank or n/a, a value of zero was given for calculation purposes. For income, an answer of "other" was given a value of zero. Other ambiguous answers (such as "I don't know" or "?") were changed to zero as there was no way to guess the correct value. Respondents who provided Matagorda as their zip-code were given a mileage of 9.24 m which was the distance from the city center to the beach road, as determined on MapQuest. Also, three respondents did not fill out any of the values used in the economic calculations therefore they were removed from analysis.

Table 9. Use-value calculations and raw data for examples from each sample period.

General Data			Pilot	On Season	Off Season	Spring Break
Zip Code			77414	77450	77515	77461
Distance (miles)			33.28	100.01	60.16	65.83
Days in Matagorda this trip			1	2	1	1
Trips per year to Matagorda			10	3	6	3
Use Values						
Costs	Variable	Components				
Direct Costs	= Access Fee		$6	$6	$0	$10
Indirect Costs	=Transport Fee + Daily Supplies + fixed Costs +Accommodation Costs + Other		$268.30	$955.01	$103.09	$97.92
	Transport Fee	=Mileage Reimbursement * 2	18.30	55.01	33.09	32.92
	Daily Supplies	=Supplies near Matagorda * days in Matagorda	20	150	20	15
	Fixed Costs	=Fixed Costs/trips per year to Matagorda	200	300	0	0
	Accommodation Costs	=Accommodation Costs * (Days - 1)	0	250	0	0
	Other		0	0	0	0
Intrinsic Values	Opportunity Lost = (Days off Work)*(Hourly Pay)		$0	$0	$0	$0
	Salary		90,000	90,000	30,000	50,000
	Hourly Pay		45.00	45.00	15.00	25.00
	Days Off Work		0	0	0	0
Total Cost =(Direct + Indirect + Intrinsic Values)			$274.30	$961.01	$103.09	$107.92

Table 10. Summary of use-values per trip to Matagorda for each sampling date.

Sample Period		Direct	Indirect	Intrinsic	Total
Pilot (N=17)	Mean	6.00	848.61	42.36	$896.972
	Sum	102.00	14,426.37	720.18	15,248.52
	Min	6.00	48.71	0.00	63.01
	Max	6.00	11,032.21	134.39	11,055.29
On-Season (N=46)	Mean	6	1030.30	76.98	$1,113.27
	Sum	276.00	47,393.69	3,540.95	51,210.53
	Min	6.00	47.11	.00	67.31
	Max	6.00	13,793.03	381.33	14,180.36
Off season (N=12)	Mean	.00	555.73	109.70	$665.43
	Sum	.00	6,668.73	1,316.43	7,985.15
	Min	.00	69.38	.00	82.87
	Max	.00	3,197.87	986.78	3,197.87
Spring Break (N=35)	Mean	10.00	1,487.60	148.99	$1,646.59
	Sum	350.00	52,066.14	5,214.60	57,630.68
	Min	10.00	41.28	.00	54.80
	Max	10.00	35,242.12	939.53	35,553.77
Total (N=110)	Mean	6.62	1095.95	98.11	$1,200.68
	Sum	728.00	120,554.93	10,792.16	132.074.89
	Min	.00	41.28	.00	54.80
	Max	10.00	65,242.12	986.78	35,553.77

3.4 Discussion

3.4.1 What do the survey results mean?

The survey results provide a basic understanding of the type of people who use Matagorda Peninsula to recreate. Demographics are varied in age, income, distance travelled, purpose of visit, group size, number of cars used and trip length. It is not surprising that these characteristics are varied amongst the respondents as the coast has been culturally one of the biggest attractions and offers many different types of activities (Douglass 2002). Also, the direct cost of the beach is very low ($6-$10) as compared to other activities such as amusement parks which can cost $50 per person a day. This is very attractive to families who want a low cost activity that can entertain their children. Other aspects of the beach, such as lack of restrictions on alcohol and dogs, fishing, beach walking and shell collecting, attract other types of users. The beach has something to offer almost anyone.

The Likert statements about perceptions produced some interesting results. It is not surprising that most of the users find the beach safe overall since this is the place they choose to recreate. Beach driving did present safety concerns during Spring Break, most likely due to the density of users. Visual observations showed that Spring Break sampling period had a high level of beach users who often had large trucks that were causing the beach road to be very un-drivable. Many cars were getting stuck and not much maintenance was occurring to smooth the sand. Also, it is more visually obvious that beach users are partying and showing off which causes other users to feel unsafe.

Of the activities listed, most were found to be enjoyable however the majority of respondents did not find off-roading/ATV activities to be enjoyable. This result is most likely due to the fact that off-roading/ATV activities are illegal on Matagorda Peninsula therefore people who value this activity probably go elsewhere. Another issue is that people may not have answered the question honestly due to the legal issues associated with this activity.

The one activity that had different responses during different sampling periods was bird watching which was most enjoyed during the Off Season and least enjoyed during Spring Break. This result is counter-intuitive since bird populations are usually correlated with spring and summer time periods. However, due to the increased population of people using the beach during those times, birds may not be as present or as observable as during the Off season.

The beach was mostly considered well maintained by the overall results. Trash levels and facilities adequacy were most acceptable during the Off Season and least during the On Season. Trash level perceptions most likely can be contributed to the amount of beach users during these times. Facility adequacy most likely can be contributed to the general style of visit during the different season. During the Off Season, many users were observed at the beach for short periods of time, such as five minutes or an hour. Observations showed that people would come to just “see” the beach and take pictures, walk dogs, look for shells or fish. During the summer, people were observed for longer periods of time on the beach, in big groups with tents or shelters and often stayed multiple days. Therefore, these different styles of visits would require different needs for facilities.

One of the few statements that the majority of respondents disagreed with was that access fees were too high. The Off Season respondents did agree with this statement more than the other time periods. This is a strange result as access fees are often not necessary during the Off Season and this could have resulted in respondents having difficulty answering this question. Many may have answered "N/A" which could have skewed the results. However, the Off Season respondents thought that the access fees were used appropriately while the Spring Break respondents thought they were not used appropriately. This can be related back to the driving safety issues. Many respondents commented that the access fees should pay for better beach road maintenance. Since the beach was least drivable during Spring Break, these two items are most likely related.

The last part of the Likert statements focused on the presence of seaweed in Matagorda. While the majority of users agreed that seaweed did not deter them from the beach and thought it was important to the ecosystem, they were undecided on whether the seaweed should be left in place on the beach. However, the majority of respondents was opposed to it being completely removed from the beach and was in favor of it being moved to the dunes. This is important to acknowledge because it indicates how management strategies could be implemented in a way that would please many users while providing for important ecosystem services. It indicates that this management practice may be an acceptable practice in which money should be invested in-order to increase the attractiveness of Matagorda. For example, based on the survey responses, facilities did not need improvement, however new facilities were just created at the beach entrance. Unfortunately, new facilities may not have been the best place to invest money in order to increase the attractiveness of the beach to users.

The results for the ranking section correspond to the Likert results. Overall, safety and cleanliness were the most important aspect of Matagorda and off-roading and water sports were least important. Due to the nature of the activities, it is hard to get people who enjoy water sports to fill out a survey as they are often busy in the water performing the activity. Three characteristics showed difference in raking from the four sample periods. Cleanliness ranked low during the Pilot study and high during the Off Season. Nature ranked high during the pilot study, but low during the Spring Break season. Off roading was ranked lowest by Spring Breakers. In agreement with Likert results, both trash and road maintenance were two aspects that needed the most improvement while seaweed maintenance and facilities needed the least improvement. In terms of seaweed management, this indicates that people are satisfied with the present maintenance procedures. Trash was ranked high by the On Season study which could be due to the amount of people using the beach at that time.

Some issues with the survey need to be addressed. While the survey was administered to a focus group and pilot study, there may still be some ambiguity with some of the wording in the survey. Particularly the term “off-roading” may have been confusing to the respondents. While the authors intended “off-roading” to describe activities involving ATV’s in the dunes, some respondents might have inferred it to mean any driving on the beach, or off the paved roads. This could have caused error in the responses.

Also, survey bias could have been introduced, based on the sampling periods and the respondents that were approached. An attempt was made to approach as many users as possible. However, time was an issue and approaching users that appeared to be busy was deemed an inefficient use of time. As described in the methods, the administration of the surveys was altered during the samplings to try to contact as many people as possible. In order to approach people who were eating or fishing or in the water or just leaving the beach, users were given flyers or self-addressed surveys. Flyers were left on cars if users were not nearby. While water users were hard to approach, some were approached while leaving the water (such as surfers or kayakers) but often were wet, had their hands full, and were not interested in filling out a survey. This could have led to a negative bias against watersport activities. The use of self-addressed envelopes seemed to be the most effective and efficient way to collect the greatest number of surveys. Also, being able to collect more frequently during different times of the day and days of the week would help to get a more representative sample of users. Having additional surveyors to administer the survey would also increase the number of respondents.

Another issue is whether the results were influenced based on when/where the respondents filled out the survey. When the respondents were filling out the survey in the field, they may have been better able to remember or recall their trip, but may have felt rushed. While the surveyor stood off to the side of the respondent, the respondent may have felt hesitant to answer questions honestly. However, if the respondent had taken the survey home, the respondent may have less accurately recalled the trip. Further analysis of differences between survey administration methods (paper based in person, envelope or internet response) could determine if there were any effects based on the methodology.

Table 11. Coastal resource evaluation methods.

Coastal Resources Evaluation Methods			
Information	**Methods**	**Source**	**Raw Economics**
Economic Valuation of Coastal Resources	Sediment Values	online values for recent nourishment project on Sargent's Beach (north)	How much financially is lost due to hurricanes based on sediment loss
	Property Values	Housing/Taxes information from internet	How much is the land worth
Social Perspectives of Users	Beach Use Values	Beach access fees Questionnaire Survey	How much are people willing to pay for beach access How much people are willing to pay for a beach activity How much is the beach worth for a given day. A given season. A given year.
	Beach User Demographics,	Questionnaire Survey	What people are using the beach How much of people's income is being spend on beach activities
	Beach User Perspectives	Questionnaire Survey	What are the most important coastal aspects
	Beach User Opinions	Questionnaire Survey	What do people feel about the beaches they use What activities/facilities do they value the most
	Beach User Economic valuation	Questionnaire Survey	What are the best changes to management strategies based on what users are interested in using CBA? How much money does the beach bring to Matagorda county in travel costs?
	Other Stakeholders	RV Park visitors Nature Center Visitors	Are there other attractions to Matagorda besides the beach? What do people find most important in the town?

The economic analysis provided some interesting insight to how much a beach trip costs. The direct cost was minimal compared to the overall use value. This is important because cost benefit analyses often only take into account direct costs. However, the highest proportion of the use value came from the indirect cost. The results provided an average use value of Matagorda beach per person as $1,200.68. Overall, the minimum use value was $54.80 per person and the maximum was $35,553.77 per person. The average was lowest for Off Season respondents at $665.43 per person and highest for Spring Break respondents at $1,646.59 per person. The ranges of values for indirect and intrinsic values were also quite broad. This shows that a high number of respondents are needed to produce an adequate average use value of the beach and all three aspects are integral to determining how much coastal resources are worth.

3.4.2 Alternative Economic Valuation Methods of Coastal Resources on Matagorda Peninsula, Texas

While this research indicated use value in regards to direct, indirect and intrinsic values of beach users, other methods of economic valuation can provide more insight to the total economic value of coastal resources(Table 11). Three other aspects of the coast, sediment values, property values and other stakeholders, will briefly be discussed with suggestions for evaluation. A combination of these methods would help to produce a more holistic valuation of coastal resources.

The value of sediments can be correlated to the cost of beach re-nourishment. The costs to extract sediment, transport it and place on beach are included in the overall monetary value of re-nourishment. Smith et al. (2009) report that between 1950 and 2002, nourishment projects cost $2.5 billion in 2002 dollars in the US. Since there is not a recent nourishment project in Matagorda Peninsula, the estimated sediment cost of re-nourishment would have to be extrapolated from an existing or previous project nearby. There are two examples of project costs in Texas during the year 2000 found in the "Beach Nourishment: A Guide for Local Officials" on the National Oceanic Atmospheric Administration's website for (NOAA 2002). In Galveston, a project placed $542,833.9 m^3 over 5,672.2 m of land at an estimated cost of $5,900,000 or $8.31/yd^3. In Gilchrist on Bolivar Peninsula, a project that placed 229,336.4 m^3 over 1,600 m had an estimated cost of $1,200,000 of $4/yd^3. A potential problem with this valuation technique is transferability of one nourishment project to another on a different study site (Barton 2002, Plummer 2009, Ruijgrok 2001).

Property values can be used through hedonic pricing to estimate value of the coast. Housing developments at coastal areas are usually high priced and in risky locations, however, there is an intrinsic value to living near the coast. Property values for Matagorda can be found on the public internet site "TaxNetUSA". Data collected from 541 properties in Matagorda in close proximity to the beach during July 2009 (Table 12) indicate an average value of $175,941.43. The downtown area of Matagorda is separated from the beach by a bridge where the Colorado River intersects the Intracoastal WaterWay. The bridge and waterway were considered the boundary for considering properties as being in close proximity to the beach (property to the south of the bridge were counted in the analysis).

Table 12. Statistics of Matagorda property values south of the Colorado River/Intracoastal WaterWay Bridge.

Property Values of Matagorda Peninsula				
N	Total	Average	Min	Max
541	$95,184,311.00	$175,941.43	$1,150.00	$2,000,000.00

There are other stakeholders in the coastal community besides beach users. Data acquisition to evaluate other stakeholders would require additional surveying of the users of local attractions and interviews with owners of local business. Some suggested focus groups for future studies include visitors to the Matagorda Bay Nature Center and campers at the RV Park managed by the Lower Colorado River Authority (LCRA), owners and customers of local commercial entities, such as the Stanley's gas station and market, restaurants, hotels and marinas, and fishermen. The prominence of the Colorado River results in many fishermen enjoying boating activities which required other valuable resources, such as high quality water, fish, bait and access to the river.

There are many factors that contribute to the value of coastal resources. These methods may be complementary, additive or exchangeable depending on how one views the resources at the coast. However, it is important to remember that there are many overlapping factors that contribute to coastal value.

3.5 Conclusion

Understanding the types of users through demographic information and what they value most at the beach is integral to developing future management strategies and goals. Public perceptions and opinions are important to know in order to attract more recreationalists while continuing to please the current ones. Likert scaling and ranking of coastal characteristics along with demographic and economic questions through a public questionnaire is one method to collect this information from beach users. Alternative economic valuation methods, such as cost of beach nourishment, property values and analysis of community stakeholders, can contribute more information about the coastal community. Economic valuation of coastal sediments and developable land can provide a monetary value for preserving the integrity of the environmental aspects while enhancing the economic needs of the community. Beach use values, such as provided here through demographics, perspectives and economic valuation, can be used to develop beach management strategies that meet social needs and desires while also enhancing economic benefits.

4. USING NATURE AS A RESTORATION SOLUTION: SARGASSUM AS A FERTILIZER FOR A VARIETY OF DUNE PLANT SPECIES

4.1 Introduction

In Texas, *Sargassum fluitans* and *natans*, types of brown alga commonly known as gulfweed or simply as sargassum, are the main component of wrack (Gower et al. 2006). Masses of sargassum that are hundreds of meters wide are deposited by currents and wind from the Sargasso Sea and collect along the forefront of the beach (Tanaka and Fosca 2003). Beach raking is the most common method to deal with sargassum. Typically, the wrack is moved by mechanical equipment to the base of the dunes (Conaway and Wells 2005, Dugan et al. 2003, Gheskiere et al. 2006, Nordstrom et al. 2006, Williams et al. 2009).

Wrack is beneficial to coastal ecosystems by providing a nutrient subsidy for flora and fauna (Bouchard and Bjorndal 2000, Heatwole 1971, Hemminga and Nieuwenhuize 1990, Ince et al. 2007, Lewis et al. 2007, Orr et al. 2005, Polis and Hurd 1995). Additionally, wrack can help control erosion at the beach front by absorbing wave energy, trapping sand and helping to build embryonic dunes (Feagin et al. 2005, Gheskiere et al. 2006). Plants can also help to stabilize the dunes and provide a stronger defense to erosion by trapping and binding sand (Bressolier and Thomas 1977, Conaway and Wells 2005, Kuriyama et al. 2005, Labuz and Grunewald 2007, Lancaster and Baas 1998, Mountney and Russell 2006, Stallins 2005, Udo and Takewaka 2007).

Dunes are extremely valuable features of the coastal ecosystem (Costanza and Farley 2007, Costanza et al. 2007, Martinez et al. 2007) as they protect landward structures that are important to humans. Many beach management practices that are centered around anthropogenic desires create an attractive environment for tourists, but can detrimentally affect long-term dune integrity (McGlashan and Williams 2003, Perez-Maqueo et al. 2007). Protecting and restoring dune structures is important in maintaining the integral functions of the coastal ecosystem (Costanza and Farley 2007, Costanza et al. 2007, Martinez et al. 2007) as well as landward structures important to humans.

Sargassum can provide a subsidy to the ecosystem and act as a fertilizer to encouraged plants to grow on the newly created dunes (Anthony et al. 2006, Tsoar 2005). Studies have indicated that sargassum-based tannins have enhanced seedling growth (Sivasankari et al. 2006) and liquid fertilizers have increased the germination of seeds (Trono Jr. 1999). Williams (2007) studied the addition of different treatments of sargassum on individuals of *Panicum amarum*. This experiment found that a relatively large amounts of sargassum, placed either on top of the sand or mixed into the soil that was left in its natural condition (not washed off), resulted in the greatest amount of plant growth as compared to other treatments and a control.

However, previous studies have not resolved the specific mechanism that causes increased plant growth with sargassum as a fertilizer. Also, it is unclear how sargassum would affect a variety of dune plants. Species may respond differently to sargassum due to their specific physiognomic characteristics, such as rhizomes, or due to their response to abiotic characteristics of the ecosystem, such their exposure to salt spray or inundation (Álvarez-Rogel et al. 2007, Gilbert 2008). It is important to know the effects on other species to be sure that additions of sargassum will not create a monoculture of *P. amarum* through competition.

To address these questions, we will test the effect of sargassum on different species of plants by adding variable sargassum treatments to greenhouse plants. First, we will compare the survival rates of five plant species to determine if the species react differently to the treatments. Second, we will determine how the different sargassum treatments affect the individual plants species. Two factors we will study are the "condition" of the sargassum (washed or unwashed) and the "frequency" of the additions (once or multiple). We will compare the results of each of these factors along with comparisons to plants without sargassum (control). Lastly, nutrient analysis of sargassum will be done to determine the mechanisms responsible for potential growth enhancement of the plants. This project aims at determining whether sargassum can be used as a fertilizer for a variety of dune plants, which would aid in restoring relatively natural dune systems.

4.2 Methods

4.2.1 Greenhouse

Plants were purchased from Green Seasons Nursery (Parrish, Florida) in April 2008 and grown in a greenhouse at Texas A&M University (College Station, Texas). Plants were established in individual pots with sand from a local sand pit of grain size comparable to typical dune sand in Galveston, Texas. The five species used were *Helianthus debilis*, *Ipomoea stolonifera, Panicum amarum*, *Sporobolus virginicus* and *Uniola paniculata*. These plants are found on the Texas dune systems (Britton and Morton 1989, Hester et al. 1994, Palmer 1975, Tiner 1993), from the beach front to the back of the dunes (Table 13). *P. amarum* and *U. paniculata* and *Helianthus* grow on the top of the dunes. *S. virginicus* grows on the embryonic dunes and the beach. *I. stolonifera* grows along the dunes and coastal flats.

Table 13. Description of plant species.

Scientific Name	Common Name	Description	Location	Measurement
Ipomoea stolonifera	Beach morning glory	flowering vine	coastal flats, dunes	Amount of leaves, amount of buds
Sporobolus virginicus	Seashore dropseed	grass	back beach, embryonic dunes,	Height
Helianthus debilis	Beach sunflower	flowering plant	back beach, dunes	Amount of leaves, amount of flowers
Panicum amarum	Bitter Panicum	grass	top of dunes	Base height and leaf lengths
Uniola paniculata	Sea oats	grass	top of dunes	Height

Each species of plant was subjected to five treatments, resulting in 25 different treatments overall. A control treatment of plants grown without sargassum was used for each species. The other four treatments will have different applications of sargassum. Eight individual plants were used for each treatment, resulting in 200 individual plants.

Sargassum was collected for the treatments from Galveston Island, TX and was transported in an identical method as the sargassum that was used in previous greenhouse studies (Williams 2007). There were two levels of "conditions" of sargassum added to the plants (washed or unwashed). Sargassum was either rinsed off by tap water or left un-rinsed to simulate direct addition from the beach.

Also, there were two levels of "frequency" of additions of sargassum (once or multiple). For both frequencies, sargassum was added at the beginning of the experiment. For treatments with multiple additions, sargassum was added two more times (once a month) which is representative of a reasonable frequency for coastal managers to disperse the sargassum along the dunes due to mechanical equipment and the amount of sargassum accumulation.

After establishing plants for three weeks, 40 of the healthiest plants for each species were replanted in larger pots. Baseline measurements were taken before treatments were administered. Additional measurements occurred once a month prior to the addition of sargassum and at the end of the 15 week growing period (as done in Williams (2007)).

The survival rates for each species were recorded at each collection time. Measurements of growth varied for each of the species. Though there were a variety of measurements taken for each plant, the most appropriate measurement for analysis for each species is listed in Table 13. The measurement selected for *H. debilis* and *I. stolonifera* was the change in amount of leaves and the amount of flowers or buds, for *P. amarum* was the change in overall length (base heights plus leave lengths) and for *S. virginicus* and *U. paniculata* was the height of the individuals. *P. amarum* measurements were done as described in Feagin and Wu (2005) while measurements for the other four species were done based on the characteristics of each species and measurements that could be comparable for plant growth.

Data from plants that died during the experiment were removed from the analysis. Then, overall change in the respective measurements from June to October for the surviving individuals was calculated. Growth changes were limited to within species comparisons due to the difference of measurement sources. However, survival rates were comparable across species.

Statistical analysis was done using SPSS 16.0 for Windows (Graduate Student Version, Release 16.0.1 16 Nov 2007). Survival rates were compared across species using Analysis of Variance (ANOVA). Statistical differences of growth between treatment types for each species were determined through a Two-Way Analysis of Variance (ANOVA) model. Additionally, the test for homogeneity of variances using Levene's statistic, identification of interactions of treatments and contrast statistics were performed. Then, a separate ANOVA was performed on each species using a Post-hoc Dunnett's T to determine if there was a difference between the control and any of the four treatments.

4.2.2 Nutrient Analysis

Sargassum was collected from Galveston Island, TX and was transported in an identical method as the sargassum that was used in previous greenhouse studies (Williams 2007). The condition of the sargassum (washed or. unwashed) was analyzed to determine potential differences in nutrient composition and possible affects of using tap water to rinse off the sargassum.

Washed sargassum samples were rinsed with tap water and the ten 100 ml samples of tap water that had been rinsed through the sargassum was then collected. Each filtered sample of rinse water was analyzed separately. Tap water samples were analyzed as a control. No rinsing occurred for the unwashed sargassum samples.

The sargassum samples were dried for approximately 24 hours, crushed with a rolling pin and sieved to remove any sand grains. Next, the sargassum was ground into a powder using a steel electric "flail-arm" Soil Grinder (Humbolt Mfg Co. Northridge IL 60706) and a Tecator Cyclotec 1093 Sample Mill.

The sargassum and water samples were analyzed for nitrogen (N), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) and phosphorous (P). Additionally, the sargassum samples were analyzed for carbon (C). Analysis of N in the water was conducted with flow injection spectrophotometer (AlpKem division of O.I Analytical, College Station, Texas, Model: #FS3000 with TKN -gas diffusion cartridge module). Analysis of N and C in the sargassum was conducted on the dried material by a flash dynamic combustion method using a furnace, separator, and detector manufactured by ThermoFinnigan (CarloErbaInstruments, Milano Italy, Model: Flash EA1112 carbon/nitrogen analyzer).

For the analysis of K, Na, Ca, Mg and P, the sargassum samples were subjected to a wet digestion procedure based on the method of Parkinson and Allen (1975), using a solution of sulfuric acid, hydrogen peroxide, selenium, and lithium sulfate. The samples were slowly heated for approximately six hours until the material was completely digested (i.e. liquid was clear). Before being ready for analysis, the resulting liquid was cooled, diluted, cooled again and filtered.

Analysis of K, Na, Ca and Mg for the digested sargassum and water samples were conducted with an atomic absorption flame spectrophotometer (Varian Inc., Model: SpectrAA 220 Fast

Sequential with SIPPs pump sample auto diluting system). Analysis of P for the digested sargassum and water samples was conducted with the same flow injection spectrophotometer used for the N analysis with a total phosphorous cartridge module.

T-tests were used to analyze the difference between nutrients in the condition of sargassum (washed and unwashed) and between the rinse water that passed through the sargassum and the tap water as a control.

4.3 Results

4.3.1 Greenhouse

4.3.1.1. Between Species Survival Comparisons

Since the measurements of plant growth differed for each species, survival rates are the only common variable that can be used to compare species response to sargassum. The survival rates of species (Figure 4) indicated that both *H. debilis* and *I. stolonifera* had low survival rates. A One-Way ANOVA indicated that only *H. debilis* was significantly different from *P. amarum* ($p = 0.008$), *S. virginicus* ($p = 0.024$) and *U. paniculata* ($p=0.054$) while *I. stolonifera* was not significantly different from the other species ($p >0.05$). There was no significant difference when survival rates of treatments were compared.

4.3.1.2. Within Species Measurements

Results for growth of treatments were compared within each species of plants to see if there was a difference between the two factors (condition and frequency) and between the four treatments (once washed, once unwashed, multiple washed and multiple unwashed).

Comparisons for *H. debilis* treatments were limited to a One Way ANOVA test between the conditions of sargassum in the multiple frequency factor. This was due to the fact that there were no surviving plants in the single frequency factor. The results indicated no significant difference between the two conditions (washed and unwashed) of sargassum treatment ($p = 0.710$) with a constant multiple frequency factor.

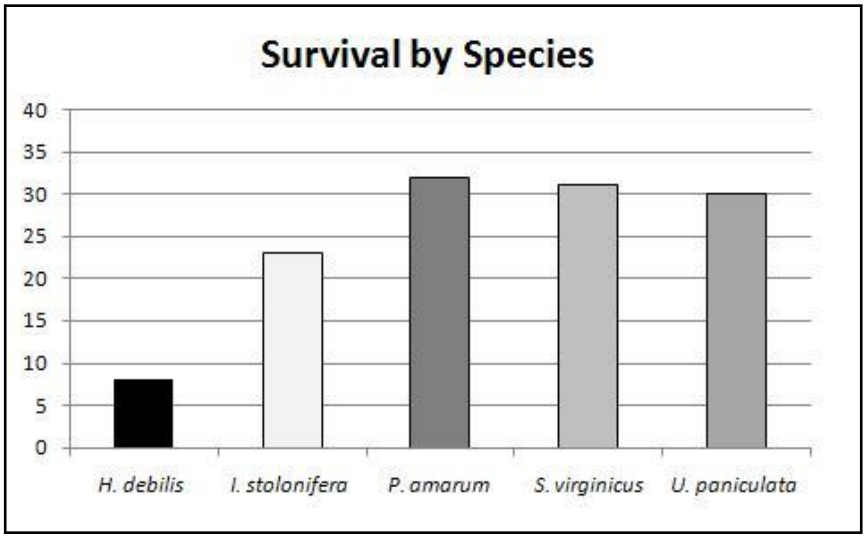

Figure 4. Survival rates of individuals.

After determining that there were no interactions between the condition and the frequency factor for *I. stolonifera*, a Two-Way ANOVA comparison for the four treatments of *I. stolonifera* (Figure 5) indicated a significant difference between the treatments of different conditions (washed vs. unwashed) ($p < 0.001$). Interactions of the condition and frequency factors were statistically significant for the other three species: *P. amarum*, *S. virginicus*, and *U. paniculata* ($p=0.006$, $p=0.001$ and $p=0.015$, respectively). Therefore, further investigation was needed to determine the mechanism that was causing plant growth.

After determining that these three species (*P. amarum*, *S. virginicus*, and *U. paniculata*) had equal variances through the test of homogeneity of variances utilizing Levene's Statistic ($p = 0.860$, $p = 0.420$, $p = 0.447$), the estimated marginal means were used to determine how the interactions were related to the two factors. The data was further examined using post-hoc contrast models (Figure 6).

Further investigation through the contrast model for *P. amarum* (Figure 6) showed that the frequency factor did significantly change the growth results for treatments overall ($p<0.001$) as well as for the treatment comparisons of the frequency factors holding the condition constant

ANOVA results for Factors										
Species	*I. stolonifera*					*P. amarum*				
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Type III Sum of Squares	df	Mean Square	F	Sig.
Conditon	484.116	1	484.116	18.096	0.001	2120.054	1	2120.054	0.279	0.602
Frequency	46.039	1	46.039	1.721	0.209	472985.500	1	472985.500	62.167	<0.001
Condition * Freque	0.039	1	0.039	0.001	0.970	67323.090	1	67323.090	8.849	0.006
Error	401.283	15	26.752			197816.300	26	7608.320		
Total	2302.000	19				844597.000	30			
Corrected Total	920.737	18				726796.100	29			
R^2 (Adjusted R^2)	0.564 (0.477)					0.729 (0.696)				
Species	*S. virginicus*					*U. paniculata*				
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Type III Sum of Squares	df	Mean Square	F	Sig.
Conditon	588.927	1	588.927	0.686	0.417	90393.520	1	90393.520	3.540	0.075
Frequency	140.079	1	140.079	0.163	0.690	3485.021	1	3485.021	0.136	0.716
Condition * Freque	14135.300	1	14135.300	16.459	0.001	179707.700	1	179707.700	7.037	0.015
Error	18894.190	22	858.827			510727.400	20	25536.730		
Total	42753.420	26				1059033.000	24			
Corrected Total	33659.490	25				825982.000	23			
R^2 (Adjusted R^2)	0.439 (0.362)					0.382 (0.289)				

Figure 5. ANOVA results for 4 treatments of 4 species.

(washed treatments: p=0.001, unwashed treatments: p=<0.001). There was also a significant difference between condition factors when the frequency was held constant as multiple additions (0.016).

The estimated marginal means for both *S. virginicus* and *U. paniculata* indicated a complex story. Individual treatment combinations for *S. virginicus* created significantly different growth responses, but neither of the two factors was uniquely responsible for the results. Individual results for *U. paniculata* indicated there was a significant difference between condition factors when the frequency was held constant as multiple additions (p=0.004). Also, *U. paniculata* had significantly different results between frequency factors when the condition was held constant as washed (p=0.016).

To determine if sargassum was producing positive growth results on the plants, a One Way Analysis of Variance (ANOVA) procedure was performed on the four treatments against the control. The procedure was not performed on *H. debilis* plants due to only one surviving plant in the control group. This made it impossible to perform the test due to a lack of error computation. For the other four species, all initial ANOVA's indicated that there were differences between the five treatments ($p \leq 0.001$). Therefore, each treatment was compared individually with a Dunnett's T Test to determine if they were significantly larger than the control (Figure 7).

Species *	***P. amarum***		***S. virginicus***		***U. paniculata***	
Comparisons of each Factor	t	Sig. ^	t	Sig.	t	Sig.
Conditions	0.528	0.602	0.828	0.417	1.881	0.075
Frequency	7.885	<0.001	0.404	0.69	0.369	0.716
Comparisons holding Frequency Constant						
Once	-1.667	0.107	3.454	0.002	-0.545	0.591
Multiple	2.578	0.016	-2.283	0.032	3.206	0.004
Comparisons holding Conditions Constant						
Washed	3.614	0.001	3.154	0.005	-1.398	0.177
Unwashed	7.399	<0.001	-2.583	0.017	2.617	0.016
* Equal Variances Assumed due to the Test for Homogeneity ^ 2-Tailed Significance						

Figure 6. Contrasts of individual treatments.

The results for *I. stolonifera* showed that when the condition was constantly unwashed, regardless of frequency, there was a significant difference from the control ($p=0.013$, $p=0.002$), while washed treatments were not significantly different ($p=0.871$, $p=0.520$). The results for *P. amarum* show that when frequency was constantly multiple additions, regardless of the condition, there was a significant difference from the control ($p=0.006$, $p<0.001$) while single addition treatments were not significantly different ($p=0.855$, $p=0.997$). The results for *S. virginicus* showed that two of the treatments, multiple frequencies with washed condition and single frequency with unwashed condition, were significantly greater than control ($p=0.001$, $p=0.001$) while the other two treatments, single addition with washed condition and multiple additions with unwashed condition, were not significantly different ($p=0.506$, $p=0.208$). The results for *U. paniculata* showed that when the condition was constantly unwashed, regardless of frequency, and when the condition was washed with a single application of sargassum there was a significant difference from the control ($p=0.006$, $p<.001$, $p = 0.007$) while the washed condition with multiple additions was not significantly different ($p=0.127$).

4.3.2 Nutrient Analysis

Results indicated that washing the sargassum increased the proportion of C, but significantly depleted N, Na and P (Figure 8). For N, Na, Ca and Mg equal variances were assumed. For C, K, and P equal variances were not assumed. There was a significant change in C ($p=0.009$), N ($p=0.003$), Na ($p=0.002$) and P ($p=0.021$) between unwashed and washed sargassum conditions. The rinsed water showed a significant increase in all the nutrients analyzed (N, K, Na, Ca, Mg and P) when compared to the tap water control ($p\leq0.001$).

ANOVA Results: Did treatments grow more than the controls?							
Compare Control with:		***I. stolonifera***			***P. amarum***		
Condition	**Frequency**	Mean Difference	Standard Error	Sig.	Mean Difference	Standard Error	Sig.
Washed	Once	-1.000	3.421	0.871	-11.279	46.547	0.855
	Multiple	2.250	3.421	0.520	146.321	46.547	0.006
Unwashed	Once	9.333	3.123	0.013	-89.817	49.761	0.997
	Multiple	12.400	3.245	0.002	258.746	46.547	<0.001
Compare Control with:		***S. virginicus***			***U. paniculata***		
Condition	**Frequency**	Mean Difference	Standard Error	Sig.	Mean Difference	Standard Error	Sig.
Washed	Once	12.889	19.174	0.506	358.083	112.484	0.007
	Multiple	65.587	17.284	0.001	200.083	112.484	0.127
Unwashed	Once	70.599	17.284	0.001	304.708	94.111	0.006
	Multiple	27.443	19.174	0.208	513.833	94.111	<0.001

Figure 7. ANOVA results for species of treatments.

4.4 Discussion

4.4.1 Greenhouse

Coastal systems are nutrient poor and many dune plants have adapted to those conditions. The species used in this experiment represent plants that grow along different areas of the beach. Each species responded slightly differently from the sargassum treatments, however, none were impaired by the addition of sargassum.

The results for *H. debilis* should be taken cautiously as the visual assessment shows that the survival rates were low for all treatments of this species. Therefore, it is probable that *H. debilis* was susceptible to death in a greenhouse, no matter what the treatments are. However, it is interesting that all but one of the surviving plants were from the multiple frequency addition of sargassum treatments. It is possible that consistent addition of sargassum can help to

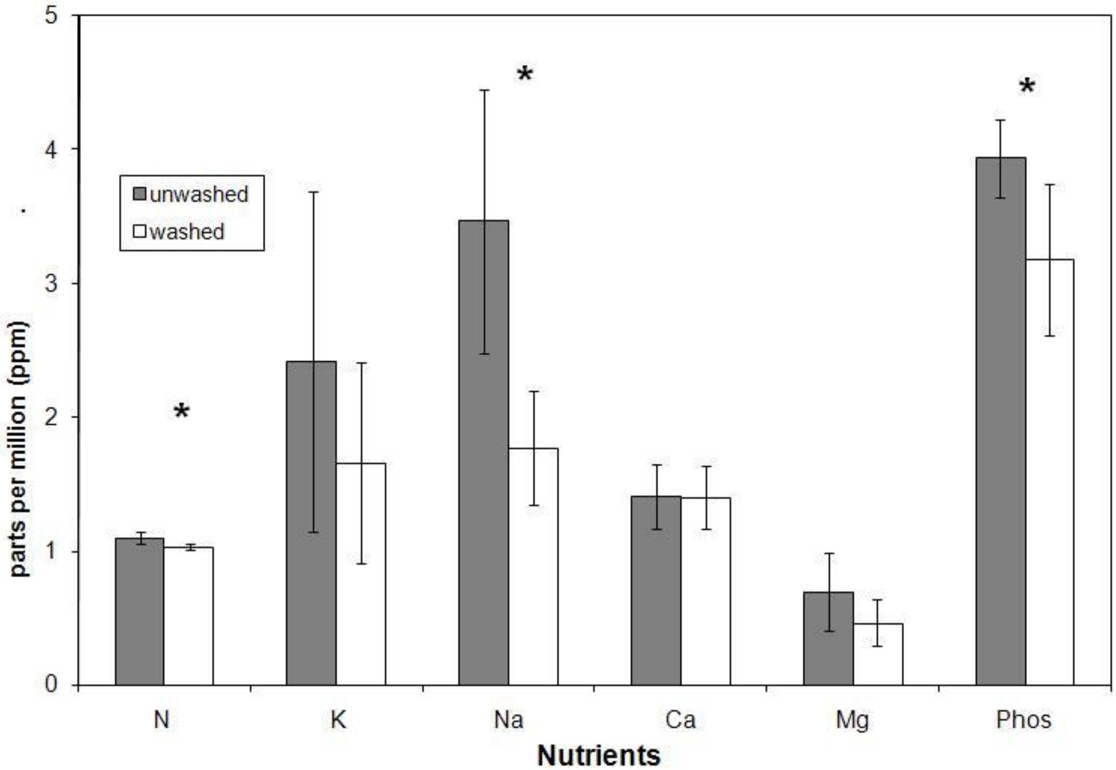

Figure 8. Sargassum nutrients. Bars represent the average nutrient amount (in ppm) with error bars represent +/- one standard deviation. Results for C have been removed from the graph.
*** Indicates significant difference in the T-Test between washed and unwashed Sargassum.**

compensate for environmental stresses the plants are experiencing, whether natural or greenhouse induced.

Though *I. stolonifera* also experienced low survival rates, it is clear that the unwashed condition of sargassum produced the most positive effects on this species, regardless of frequency of addition. This plant, typically found along the base of the dunes and in the embryonic dunes, may be better adapted to handle the material that is deposited directly from the sea as it would naturally encounter this subsidy in nature.

P. amarum, *S. virginicus* and *U. paniculata* all had high survival rates in the greenhouse, but they responded to different treatments. *P. amarum* responded best to the multiple frequency factor of sargassum despite the conditions. *P. amarum* is very versatile plant that is able to grow easily in many disturbed environments. This species probably has developed adaptations to allow it to capitalize on any additional subsidies of nutrients, despite the condition of the subsidy.

S. virginicus did not show a strong response to either of the specific factors, but instead was able to grow better in both the multiple treatments of unwashed sargassum and the single treatment of washed sargassum. Whether multiple treatments of washed sargassum added too many foreign nutrients, or that single treatments of unwashed sargassum did not apply enough nutrients, is not possible to derive from this experiment. However, it is safe to say that sargassum does not impede *S. virginicus* growth as the control treatment did not grow significantly more than any of the treatments. Therefore, further investigation would be needed to extract the best treatment with sargassum for *S. virginicus*.

U. paniculata plants responded best to the unwashed factor. It is interesting that though this plant had a similar response to the treatments as *I. stolonifera*, these plants are not usually found in the same location of the beach. However, due to some overlapping of territories, these plants may have adapted to oceanic subsidies and developed ways to capitalize on the added nutrients in similar ways in order to survive in the field.

4.4.2 Nutrient Analysis:

The nutrient analysis results show that N, Na and P were significantly depleted from the sargassum when it was washed. Dune plants are typically limited by N, K and P availability (Hester and Mendelssohn 1990, Kachi and Hirose 1983, Van den Berg et al. 2005). Washing the sargassum caused some portion of the N and P subsidy to be mobilized and lost. .

We suspect that Na may actually enhance growth of dune plants as well. Dune plants grow in an environment where they encounter salt-spray and salt water inundation and they are known to be salt tolerant (Greaver and Sternberg 2006), but future work needs to be conducted as to whether Na addition may be beneficial up to a given threshold (Howard and Mendelssohn 1999, La Peyre et al. 2001). Therefore, the loss of Na from the washed sargassum may have also caused less positive growth.

Other nutrients (K, Mg, and Ca) and micronutrients in the sargassum may enhance plant growth as well (Jobbagy and Jackson 2004), but they are unlikely to be responsible for the significant differences between the washed and unwashed sargassum, nor as the primary mechanism affecting dune plant growth in general (Hester and Mendelssohn 1990).

Therefore, this depletion of N, Na and P could explain why some of the plant species (*S. virginicus* and *U. paniculata)* were unable to significantly benefit from washed treatments. Dune plants that were able to benefit from washed treatments of sargassum, such as *P. amarum*, may be better at using a variety of nutrients.

4.5 Conclusion

Though all plants responded differently to the sargassum treatments, it is clear that sargassum does not detrimentally affect dune plants. Sargassum adds some form of nutrients as an oceanic subsidy to the nutrient poor dune environments. All plants responded positively to some form of sargassum treatment. None of the plants seemed to respond best to washed conditions of sargassum, which represent how sargassum would normally be used in gardens by local residents. Overall, plants seemed to respond well to unwashed sargassum and also to multiple additions of sargassum. This indicates that plants are adapted to capitalize on the subsidy in its natural state directly from the ocean, and in repeated amounts during a growing season. In terms of coastal management, this is a positive discovery, as it means that additional steps (therefore, additional money) would not be needed to prepare sargassum as a fertilizer for dune plants.

In terms of beach raking, sargassum would be most helpful if it could be distributed equally along the dunes, rather than in large piles as is the current method in many areas. This practice will help to promote a variety of species growth on the dunes, thereby creating a more diverse and resilient ecosystem rather than a monoculture ecosystem seen in some dune restoration projects when only one species is used (ie *P. amarum*). Since sargassum is a natural subsidy on the coast, it does not have the same risks as the use of chemical fertilizers. Overall for coastal managers, the use of sargassum as a natural fertilizer for dune plants is a positive, natural and efficient method of dealing with the natural accumulation of wrack on the beach. For coastal managers, the use of sargassum as a fertilizer could be a positive, natural and efficient method of dealing with the accumulation of wrack on the beach.

5. SUMMARY

Coasts are dynamic systems whose integrity is affected by both natural and human forces (Bush et al. 2004, Gaddis et al. 2007, Phillips and Jones 2006). While tourism is an important factor in the management decisions that occur in coastal communities, there are feedback loops in which decisions based on tourism affect natural processes. Episodic events, such as hurricanes, cause catastrophic damage to both natural and anthropogenic structures along the coast. More information about ecosystem process and function is needed to understand these effects. This research has strived to fill some of the knowledge gaps with three studies based on analyzing landscape impacts of a catastrophic hurricane, investigating beach users and their perspectives, and capitalizing on natural subsidies of sargassum to enhance dune plant growth while providing clean sandy beaches for recreationalists.

First, LIDAR was used to analyze landscape, vegetation and sediment changes on a dune system in Matagorda, TX after Hurricane Ike. Data was collected from prior to landfall to a year later in order to determine immediate impacts and the systems' ability to recover over a year. While the most loss occurred immediately after Hurricane Ike, fluctuations in gain and loss were seen throughout the year. This knowledge can help managers to make decisions about re-nourishment and recovery projects after a major storm. Understanding that some sediment might return to the system throughout a year can help in determining how much sediment volume needs to be replaced mechanically and how much can be expected to return naturally. Being aware that sediment fluctuates throughout the year (such as the erosion seen during the spring) can help to determine what time of the year would be best to implement a re-nourishment project to capitalize on natural processes, produce more successful results and spend funds most efficiently.

The results that indicate different areas of the coast react differently at similar times of they year, especially in volume of vegetation, can be used to better design restoration projects on dunes. Additionally, since high tides and tourism traffic may destroy any newly planted species, it may be best to wait until after the spring to attempt a restoration project on the dunes.

Lastly, while the comparison between aerial and terrestrial LIDAR was inconclusive, it did indicate some important criteria to consider when collecting data. Due to the differences between resolution, return points and point density, it was hard to compare the two sources of

LIDAR. Therefore, when collecting data, it is necessary to determine what you are interested in studying and how you need to set the criteria of the LIDAR systems in order to capture data that is capable of studying that aspect of the environment. In general, LIDAR data collection may improve management decisions, especially during extreme events that require quick decision-making. For long term studies, LIDAR provides a vast amount of data about coastal changes, prediction of vulnerable areas, analysis of impacts, development of preemptive protection measures and the creation of recovery plans to help save lives and protect natural resources.

The next study provided information about the public perspective and economic influx of beach users on Matagorda Peninsula. Questionnaires were used to collect data from 113 beach users during four sampling periods throughout the year. Respondents varied demographically, which is likely to do the fact that beaches are "America's playground" and tend to attract a lot of different types of users. The results showed that respondents found the beach to be safe and well maintained. Safety and cleanliness were two of the more important characteristics that attracted beach users. While access fees were not too high, some respondents were disappointed with the use of access fees. Both trash and road maintenance were deemed in need of improvement. Respondents enjoyed a variety of activities at the beach, with the exception of off-roading and water sports. Respondents felt that neither seaweed management nor facilities needed to be improved.

These results are critical in designing the next management project in order to best enhance aspects of Matagorda in order to attract tourists and keep the current users satisfied, which will ultimately build the local economy. Recently, a new facility was built at the entrance to the beach road. However, respondents to the survey indicated that facilities were already appropriate. Therefore, funds might have been better spent on cleaning up trash or providing maintenance to the beach road. Many people feel that by paying for a beach access permit, they should in return get a road that is drivable and when they do not feel that the government is reciprocating on this arrangement, they are upset and angry.

The results about how people view seaweed on the beach are also of important consideration in management decisions. Since most people do not feel that seaweed detracts from their beach experience, it may be possible to completely stop raking the seaweed and leave it in place naturally. However, if it does cause a problem, such as making the beach un-drivable, the users would feel comfortable with it being moved to the back of the dunes; however, they do not want it completely removed from the beach ecosystem. Understanding these public perceptions can help in developing management procedures that will be accepted by current users and also enhance the attractiveness of the beach for future users.

The economic analysis indicated that direct cost of beach users are not representative of overall costs. Indirect costs and intrinsic values determine a large proportion of the overall use value of the beach. The use value could be combined with other valuation methods, such as re-nourishment costs, property tax values and other stakeholder values, to determine a more holistic resource value of the coast. Information directly from beach users through questionnaires can provide coastal managers with a better idea of what is important to the beach users and help to influence policy decisions.

In the third study, the potential use of sargassum as a natural fertilizer was investigated on five different species of dune plants. Coastal processes that protect the environment are often compromised by management practices aimed to please beach users, especially when combined with the survey results. In this study, beach raking practices alter the environment of the coast by removing wrack from the fore-beach to the dunes which alters nutrients, habitat and protection. However, beach raking methods could be slightly altered to capitalize on the natural subsidies of sargassum as a fertilizer on dune plants. *Panicum amarum* showed significant enhancement of growth with the addition of sargassum, and while *Helianthus debilis*, *Ipomoea stolonifera, Sporobolus virginicus* and *Uniola paniculata* responded slightly differently to the specific treatments, none were impaired by the addition of sargassum. Overall, plants seemed to respond well to unwashed sargassum and multiple additions of sargassum, indicating that plants may have adapted to the subsidy in its natural state directly from the ocean and in repeated amounts during a growing season. This research supports the concept that sargassum deposits in the dunes would help to establish plant growth. Many coastal ecosystems are nutrient poor and have historically relied on constant or sporadic natural subsidies to the ecosystem. These results are critical in understanding the positive interactions and feedback loops between marine and coastal environments.

These studies help to provide pertinent information for understanding coastal processes and aid in developing management practices that take into consideration a holistic ecosystem. While these studies were focused on Matagorda, Texas, the results can be extrapolated to other coastal areas. However, additional field studies would need to be conducted to determine how these results would apply to the unique characteristics of each coastal system. While this research provides information on three aspects of coastal processes, there are still other aspects that would need to be considered for a complete ecosystem approach.

In order to implement any management decisions, more research on the biophysical and social aspects of the coast would need to be completed. Implementation of policy is more than just understanding the physical processes, but also has to consider the social environment in which a policy is to be implemented (Krutwaysho and Bramwell 2010). Political and physical boundaries can be detrimental to implementation. Additionally, lack of support and cooperation of the local government and other stakeholders can delay and prevent a policy from being implemented. By using an ecosystem approach that takes into consideration economic, environmental and social interests, some of these obstacles may be avoided. Also, short term goals and economic issues tend to trump long term goals and environmental issues (Krutwaysho and Bramwell 2010). By using an ecosystem approach to develop holistic management strategies, links between environmental and economic issues can be seen over the long term, making implementation of more sustainable management practices possible.

Overall, I urge coastal managers to gain more knowledge about coastal functions and processes before making management decisions. I also urge them to focus on holistic approaches that take into consideration social, economic and environmental aspects of these dynamic and intriguing ecosystems.

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APPENDIX A

EXAMPLE OF THE PAPER-BASED SURVEY

Survey Identification Number: ______________ (example: SFS001 – means summer full survey ###)

Survey on Coastal Resources on Matagorda Peninsula, TX

Thank you for participating in this survey. This survey seeks to identify the value of Matagorda Beach to you and others by discovering what resources are considered among the most important. What do you think needs to be improved? All responses will remain confidential and will only be used for research purposes. The survey is part of a Ph.D. project within the Department of Ecosystem Science and Management at Texas A&M University with approval from the Office of Research Compliance – (Protocol # 2009 – 0359).

The survey is composed of three short sections and can be completed in 5-10 minutes. For each section, read any instructions before answering. If you have any questions, please ask for clarification. Please use the answer of N/A if not applicable or you choose not to answer a certain question. The survey is also available online at **http://www.surveygizmo.com/s/145463/coastalsurvey.** Please provide the "Survey Identification Number" at the top of this page where requested during the first question. If you would prefer to fill out the survey later, you may mail it to the address below:

Amy Williams: Ph.D. Graduate Research student
Texas A&M University, College Station
Department of Ecosystem Science and Management
1500 Research Pkwy, Suite 223B, College Station, TX 77840
coastalsurvey@hotmail.com

Your Perceptions about Coastal Characteristics: Answer based on your personal opinion

Put the following in order of the most important (#1) to the least important (#12) characteristics of Matagorda Beach

_______ Beach Driving
_______ Beach Safety
_______ Camping
_______ Cleanliness
_______ Facilities (bathrooms, showers)
_______ Fishing
_______ Lack of Crowds
_______ Nature (birds, dunes)
_______ Non-driving/Recreation Area
_______ Offroading/ATV activities
_______ Travel Time from Home
_______ Water Sports (kayaking, surfing)

Put the following aspects in order of the most need for improvement (#1) to the least need for improvement (#6)at Matagorda Beach.

_______ *Beach Safety*
_______ *Trash*
_______ *Seaweed*
_______ *Beach Road Maintenance*
_______ *Nature Protection (dune stability)*
_______ *Facilities (bathrooms, showers)*

Should anything about Matagorda Beach be changed? ____

Survey Identification Number: ______________ (example: SFS001 – means summer full survey ###)

Opinions about Beach Aspects

Each of the following statements concerns the beach at Matagorda. For each, please respond on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree). If the statement does not apply to you, please select N/A (Not Applicable).

		Strongly Disagree	-------------------		Strongly Agree		N/A
1	Being allowed to camp on this beach is favorable.	1	2	3	4	5	N/A
2	Swimming at this beach is safe.	1	2	3	4	5	N/A
3	Driving on this beach is safe.	1	2	3	4	5	N/A
4	The road on this beach is well maintained.	1	2	3	4	5	N/A
5	I like being allowed to drive on this beach.	1	2	3	4	5	N/A
6	The level of trash on this beach is acceptable.	1	2	3	4	5	N/A
7	The cars do not cause cleanliness problems on this beach.	1	2	3	4	5	N/A
8	Fishing at this beach is enjoyable.	1	2	3	4	5	N/A
9	Police safety on this beach needs to be improved.	1	2	3	4	5	N/A
10	The natural aspects of this beach are well maintained.	1	2	3	4	5	N/A
11	I enjoy bird-watching at this beach.	1	2	3	4	5	N/A
12	I enjoy walking/running on this beach.	1	2	3	4	5	N/A
13	I enjoy water activities/sports (surfing, kayaking, bodyboarding, body surfing, kite surfing) at this beach	1	2	3	4	5	N/A
14	I enjoy off-roading/ATV/mudding activities at this beach.	1	2	3	4	5	N/A
15	I like to participate in family activities (picnicking, swimming, playing, etc) at this beach.	1	2	3	4	5	N/A
16	I like to participate in partying activities (dancing, drinking alcohol, listening to music) at this beach.	1	2	3	4	5	N/A
17	Facilities (bathrooms, showers) on this beach/adjacent areas are well maintained.	1	2	3	4	5	N/A
18	Facilities on this beach/adjacent areas are adequate for my needs.	1	2	3	4	5	N/A
19	The access fees are too high at this beach.	1	2	3	4	5	N/A
20	Access fees are used appropriately at this beach.	1	2	3	4	5	N/A
21	Seaweed on this beach does not deter me from recreation.	1	2	3	4	5	N/A
22	Seaweed is important for the natural ecosystem.	1	2	3	4	5	N/A
23	Seaweed on this beach should be left on the beach.	1	2	3	4	5	N/A
24	Seaweed on this beach should be moved to the dunes.	1	2	3	4	5	N/A
25	Seaweed should be removed from this beach completely.	1	2	3	4	5	N/A

Survey Identification Number: _______________ (example: SFS001 – means summer full survey ###)

Your Trip: Answer questions in regards to the trip to Matagorda when you were approached about this survey

During your trip to Matagorda when you were approached about this survey,

how many people were in your group (including yourself)? ________

how many people I your group were over the age of 18 (including yourself)? ________

how many vehicles were used by your group to get to Matagorda? ________

During your trip to Matagorda when you were approached about this survey, how many days…

from when you leave your house to when you get back, were you be away? ________

(*This question is meant to determine how long your entire trip away from home is, even if time is not spent in Matagorda)*

were spent in Matagorda? _______

Where did you start your trip from? Zip Code: ________

In a given year, approximately how many trips do you take to Matagorda (1 trip can include multiple days)?

0-1 trip   2-4 trips   5-7 trips   more than 7 trips

During your trip to Matagorda when you were approached about this survey,

did you have to take time off of work? **Yes / No**   if yes, how many days? ________

Approximately how much did/will you spend on gas for the total trip to and from Matagorda Beach? $_____

On average per day, approximately how much money (in U.S. dollars) did you spend on

on supplies (food, drinks, sunscreen, bait, etc)? **$**________

Of the above amount, how much was spent within 30 miles of Matagorda (Bay City)? **$**________

Approximately, how much money did you spend for supplies that will be used more than once (kayak, cooler, fishing rod, tent, etc)? **$** _________

If you are staying overnight….

what is the type of accommodation? Hotel   beach camping   RV camping   Other ______

what is the average cost of the accommodation per night in U.S. dollars? __________

Were there additional expenses associated with this trip that were not included above? If so, please describe them and estimate the amount per item.

$ _________ for ____

$ ________ for ____

Demographics: Please answer these questions about yourself:

Age: _____   **Gender:** M / F/ Other   **Marital Status:** Single Married Divorced Other

What is the primary purpose of your visit? *Day Trip*   *Long Vacation*   *Work*   *Other*

Circle Which Best Reflects Your Individual Annual Income (Before Taxes):

Less than $20,000   *$20,000 – 40,000*   *$40,000 – 60,000*
$60,000 – 80,000   *Greater than $80,000*   *Other or N/A*

Please use the back to provide any other comments or questions pertinent to Matagorda Beach or this survey.

Thanks you for your participation!

VITA

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Education

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Texas A&M University, College Station, TX, Masters of Forestry — Aug 2007
Rutgers, The State University of New Jersey, New Brunswick, NJ, — May 2005
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Study Abroad: University of Queensland, St. Lucia, Queensland, Australia, — Spring 2003

Research Interests: *Coastal Management, Environmental Education, Holistic Management*

Research and Teaching Experience

Graduate Research Assistant/Graduate Teaching Assistant – Ph.D. — Sept 2007- Present
Department of Ecosystem Science and Management, Texas A&M University

Graduate Research Assistant/Graduate Teaching Assistant - Masters — Jan 2006- Aug 2007
Department of Forestry, Texas A&M University

Undergraduate Teaching Assistant — Sept 2004-Dec 2004
Department of Natural Resource Management, Rutgers University, NJ

Marine Science Field Technician — Aug 2004
Rutgers University Marine Science Field Station

Research in Ocean Sciences Summer Fellow — May 2004-Aug 2004
Institute of Marine and Coastal Sciences, Rutgers University, NJ

Educational Outreach Instructor — Jun 2002-Aug 2002
Branching out of the Youth of NJ, US Department of Agriculture/ US Forest Service